

The CERES Flux-by-Cloud Type Simulator and Its Application to GCM Output

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1 - Science Systems and Applications, Inc

2 - NASA Langley Research Center

3 - Met Office Hadley Centre for Climate Change

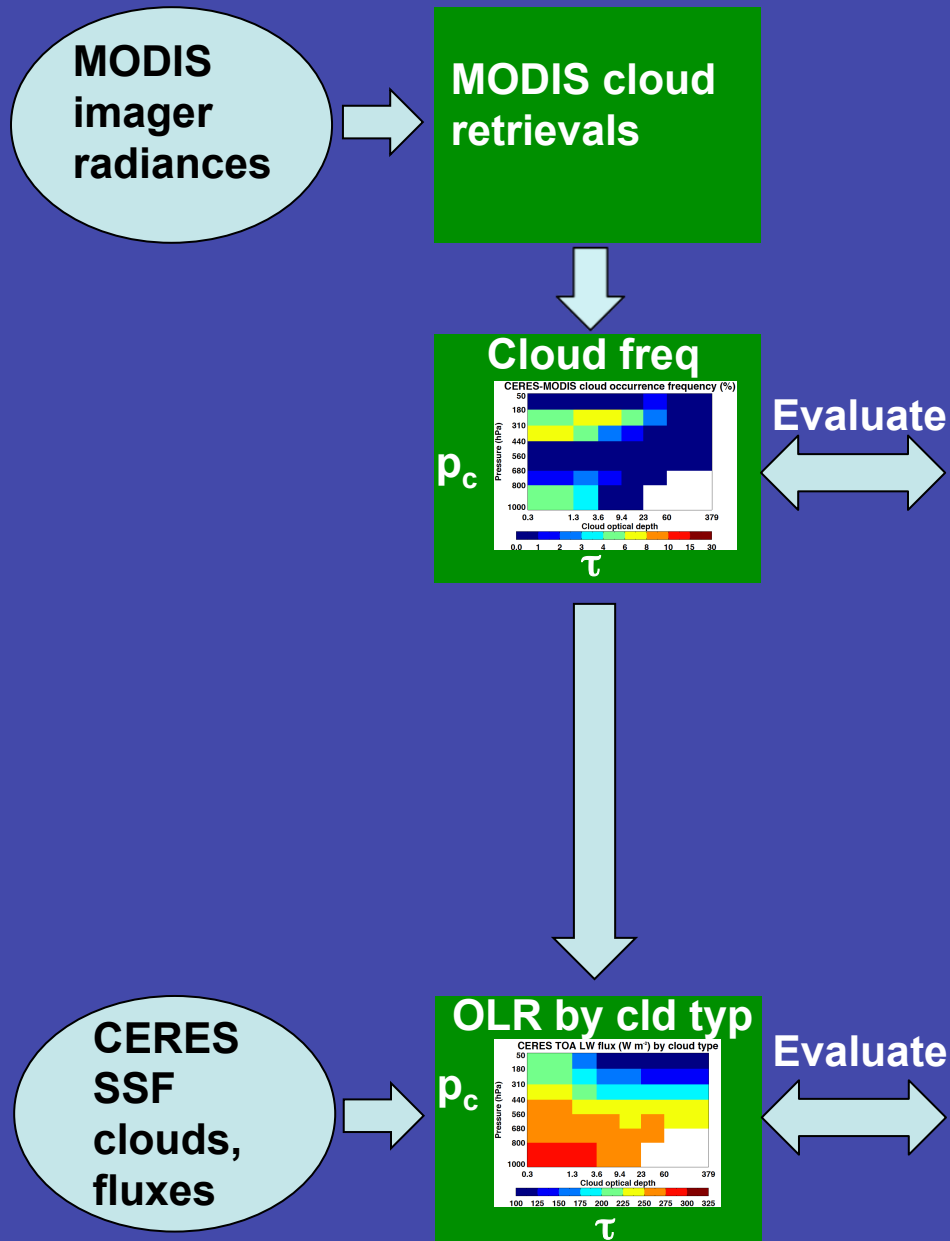
What is the Flux-by-cloud type product?

- Assigns LW and SW TOA fluxes to each observed ISCCP cloud type within a region.
- For each $1^\circ \times 1^\circ$ region between 60° S and 60° N, each daytime footprint is placed into one or more p_c - τ ISCCP-like categories based on CERES-MODIS cloud property retrievals.
- For the footprints with a single cloud type, the standard Single Scanner Footprint flux is added to that p_c - τ category.
- For footprints with multiple cloud types, narrowband-to-broadband radiance conversions are performed for each cloud type.
- Broadband radiances are converted to fluxes using Angular Distribution Models.

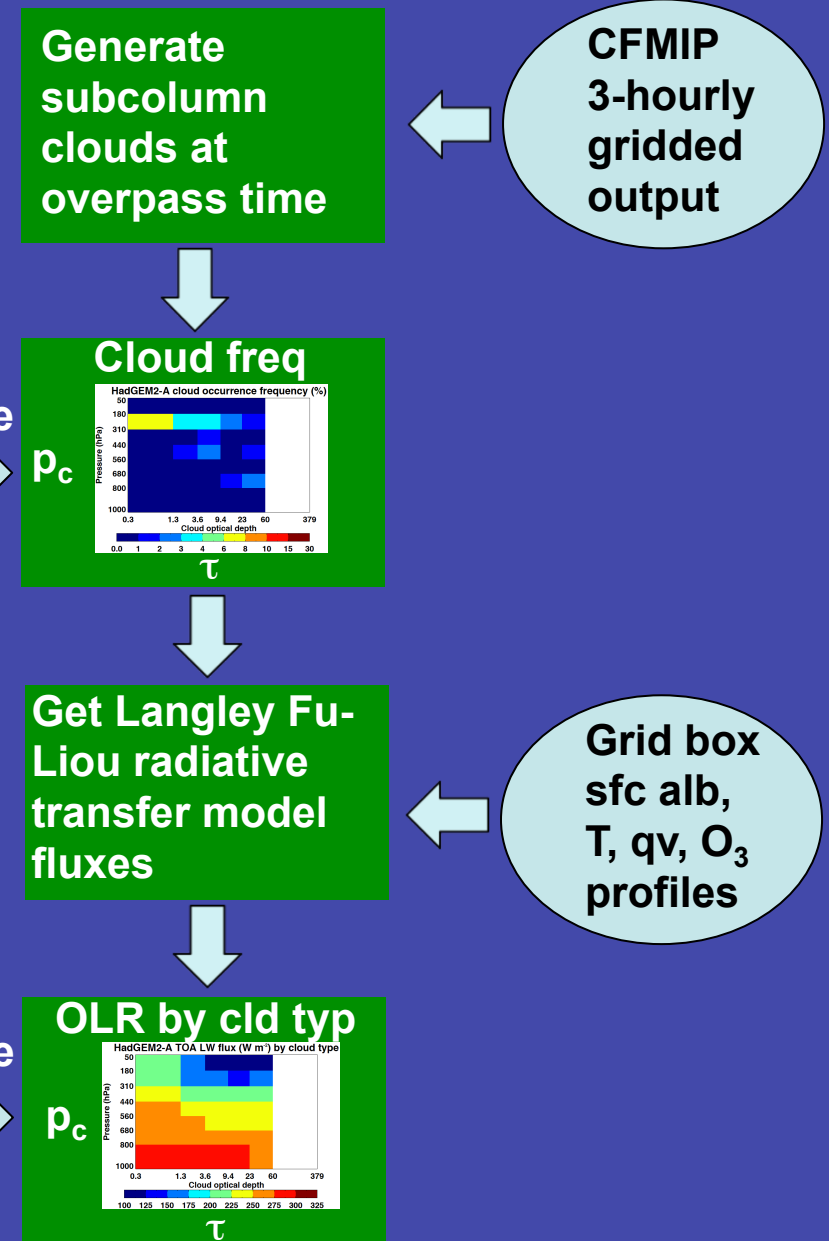
Motivation for flux-by-cloud type simulator

- Cloud properties and fluxes/albedos will be matched within 1.5 hours to the closest CERES overpass, which is important because of the large diurnal cycles in cloud fraction, τ , and p_c in many areas.
- Breaking out the flux by cloud type can help isolate physical parameterizations that are problematic (e.g., convective clouds, boundary-layer parameterizations, or processes involving surface albedo), and provide a test for new parameterizations.
- Having the radiative properties for each τ and p_c provides more information than the cloud frequencies alone, since there can be significant variations in albedo and OLR within a given p_c - τ cloud type, and ice clouds are treated differently among GCMs.
- Diagnoses using flux-by-cloud type combined with frequency of occurrence can also help determine whether an unrealistically small or large occurrence of a given cloud type has an important radiative impact for a given region.

CERES FluxByCloudType Product



CERES Flux-by-cloud Type Simulator



Reducing RT calculations

The maximum-random overlap assumption produces a large number of identical profiles within the 1000 total profiles created. We only perform one RT calculation per unique profile (there can be more than one profile associated with a p_c - τ cloud type).

	Number of calculations	Number of grid cells	Calculations per cell
JFD 2008	38956272	1573931	24.8
MAM 2008	38139748	1578995	24.2
JJA 2008	37642400	1591427	23.7
SON 2008	36438316	1590258	22.9
All 2008	151176736	6334611	23.9

Flux consistency check

- In order to verify that the simulator produces fluxes similar to those of HadGEM2-A, TOA LW and SW fluxes were calculated by the simulator for ~1.5M cases at locations between 60° N and 60° S for JFD, MAM, JJA, SON 2008 and the fluxes averaged over all of the subcolumns were compared to the grid cell mean fluxes.

	SW Bias (W m⁻²)	SW RMS (W m⁻²)	LW Bias (W m⁻²)	LW RMS (W m⁻²)
JFD 2008	-1.5	14.4	-1.6	3.4
MAM 2008	-0.9	15.0	-1.4	3.8
JJA 2008	-0.9	14.4	-1.4	3.9
SON 2008	-1.6	14.3	-1.6	3.5

Southeast Pacific results

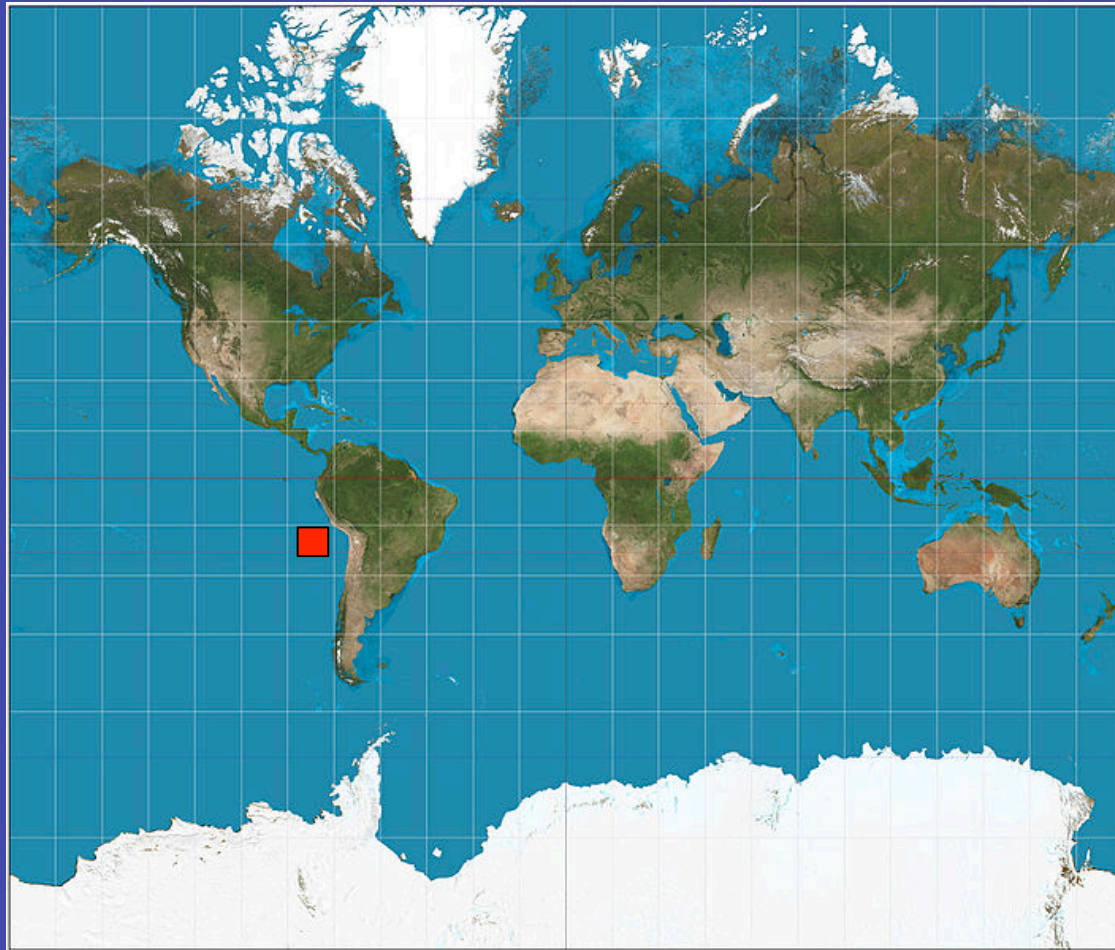
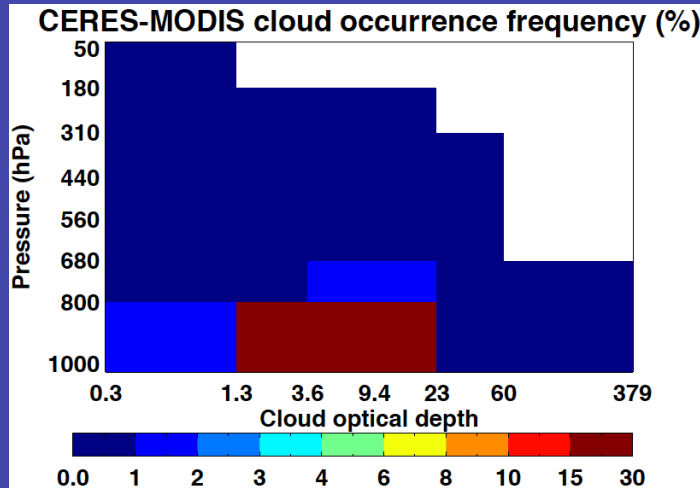


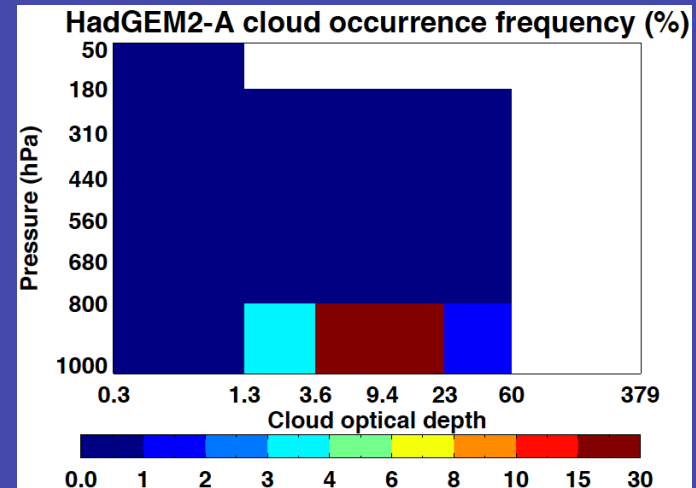
Image from Strebe, https://commons.wikimedia.org/wiki/File:Mercator_projection_SW.jpg

Cloud fraction (%) for CERES, HadGEM2-A over SE Pacific (JJA 2008)

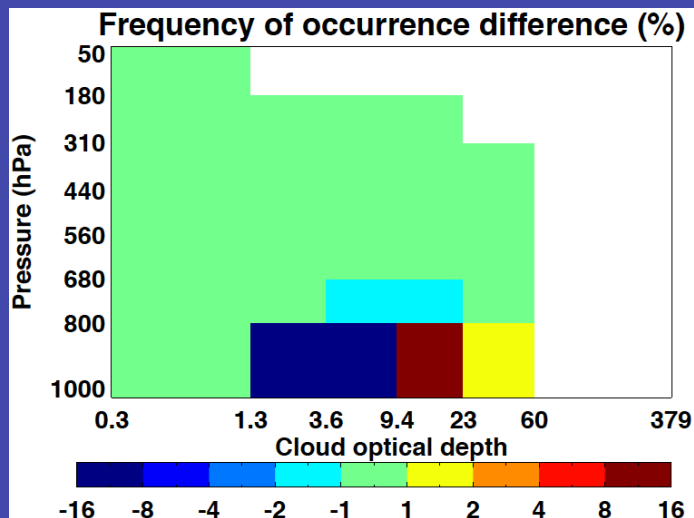
CERES



HadGEM2-A



HadGEM2-A – CERES



Grid-mean total cloud fraction:

CERES: 0.801

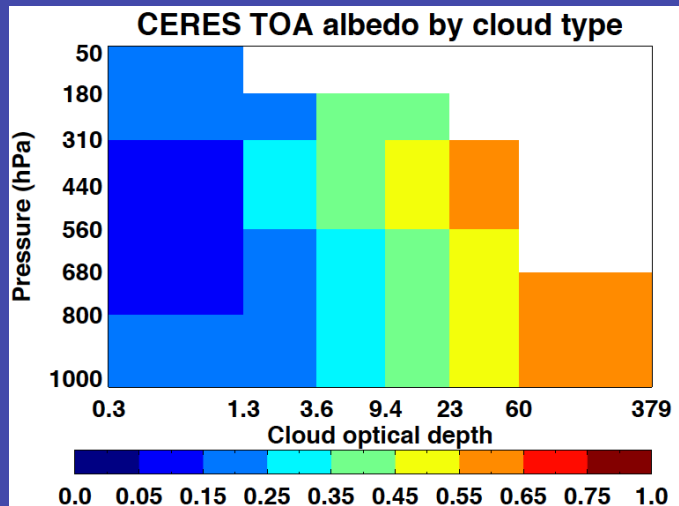
HadGEM2-A: 0.658

Cloud fraction weighting

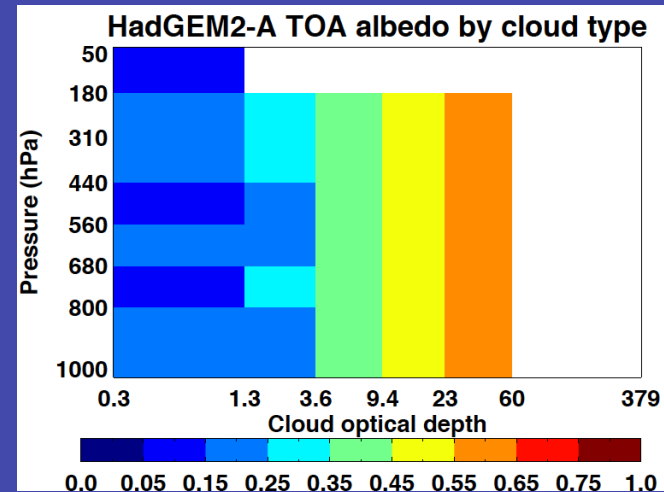
- Many possible ways to do this, but we opted to choose a method that preserves the sign of the LW flux/albedo difference and is large if the CERES and/or HadGEM cloud fraction is large.
- $\Delta\text{OLR}_{\text{cf}} = 0.5(f_{\text{H}} + f_{\text{C}})(\text{OLR}_{\text{H}} - \text{OLR}_{\text{C}})$
- Quantities are multiplied by 100 in figures to account for small magnitude of most cloud fractions.

TOA SW albedo by cloud type for CERES, HadGEM2-A over SE Pacific (JJA 2008)

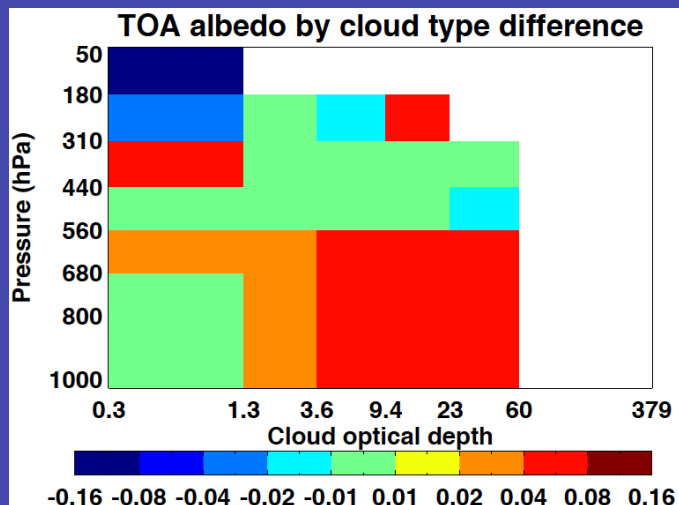
CERES



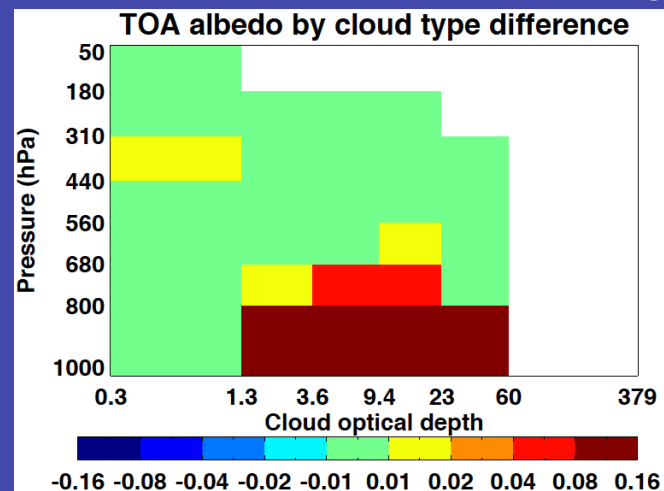
HadGEM2-A



HadGEM2-A – CERES



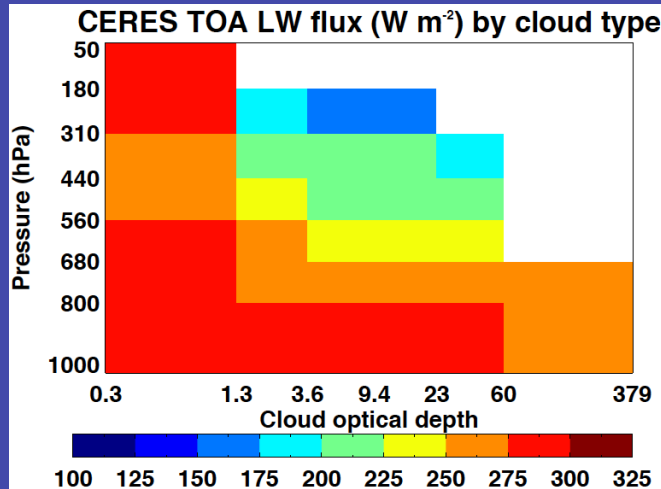
HadGEM2-A – CERES (CF-weighted)



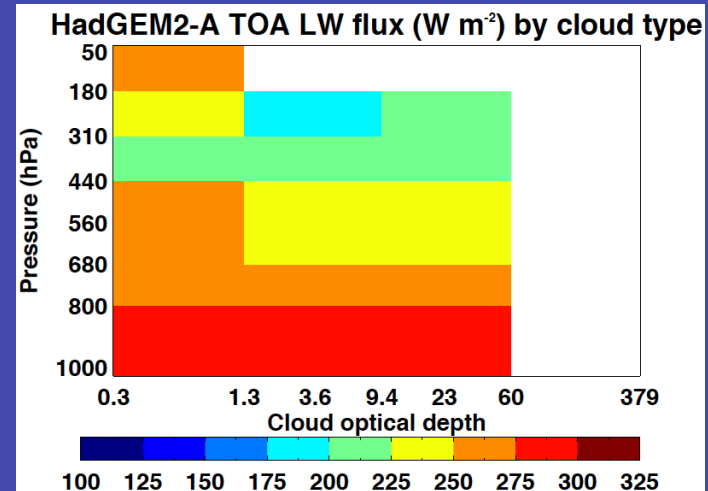
Grid-mean all-sky SW albedo: CERES: 0.274 HadGEM2-A: 0.324

TOA LW flux by cloud type (W m^{-2}) for CERES, HadGEM2-A over SE Pacific (JJA 2008)

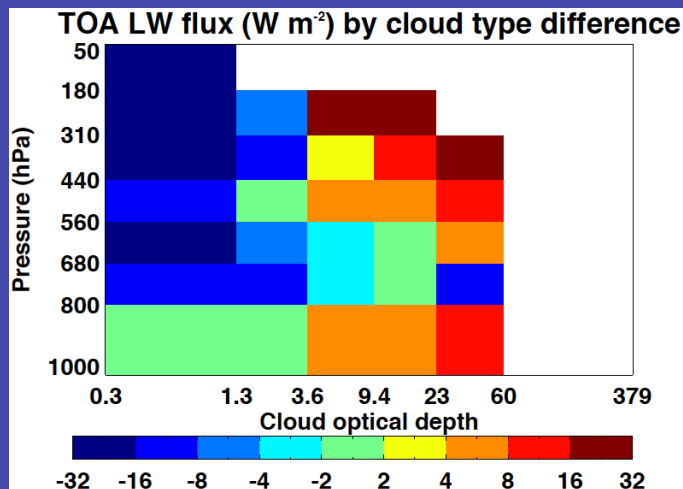
CERES



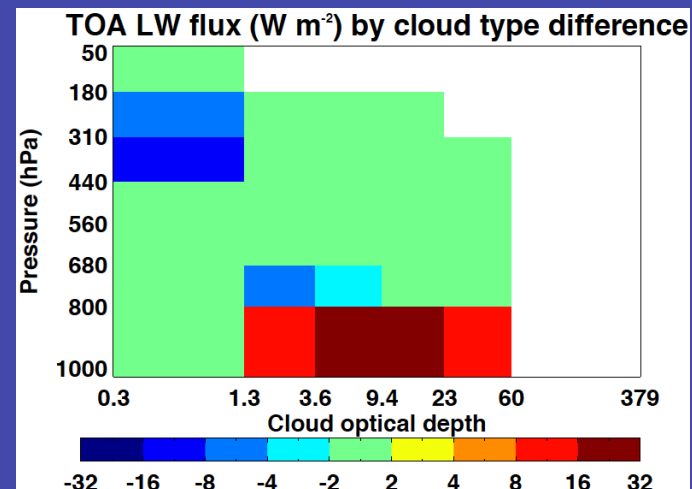
HadGEM2-A



HadGEM2-A – CERES



HadGEM2-A – CERES (CF-weighted)



Grid-mean all-sky OLR: CERES: 279.9 W m^{-2} HadGEM2-A: 289.0 W m^{-2}

60° N – 60° S results

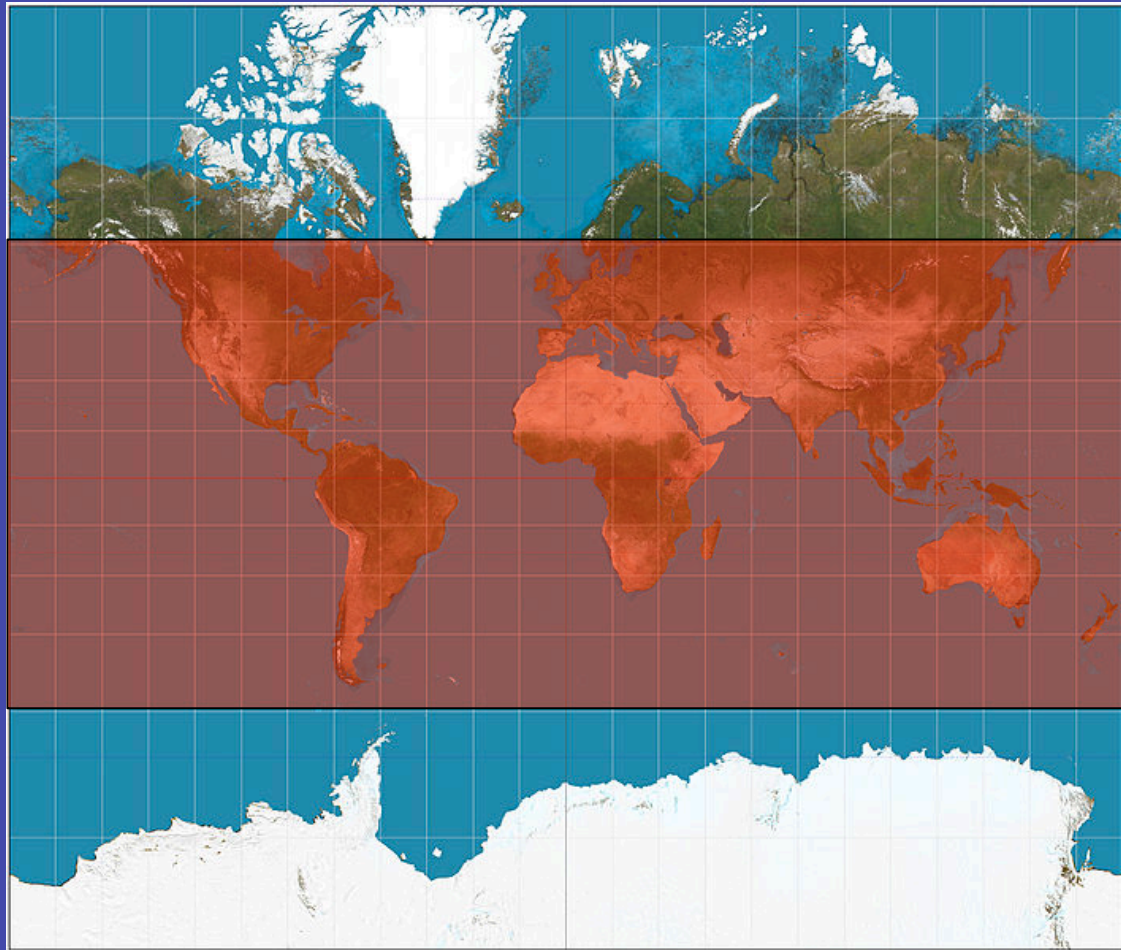
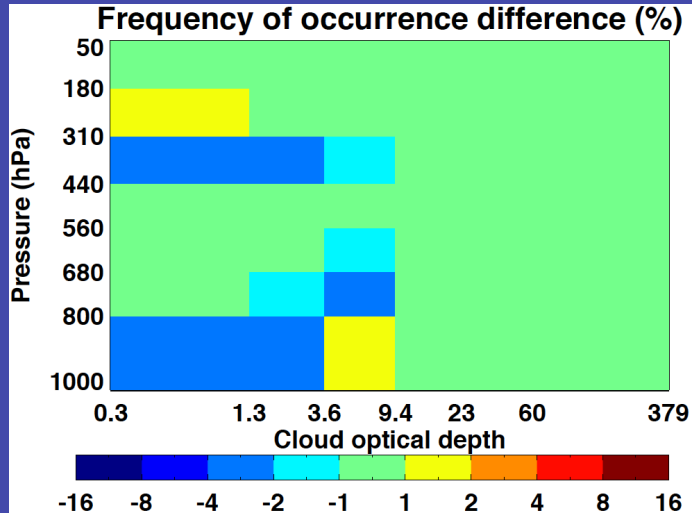


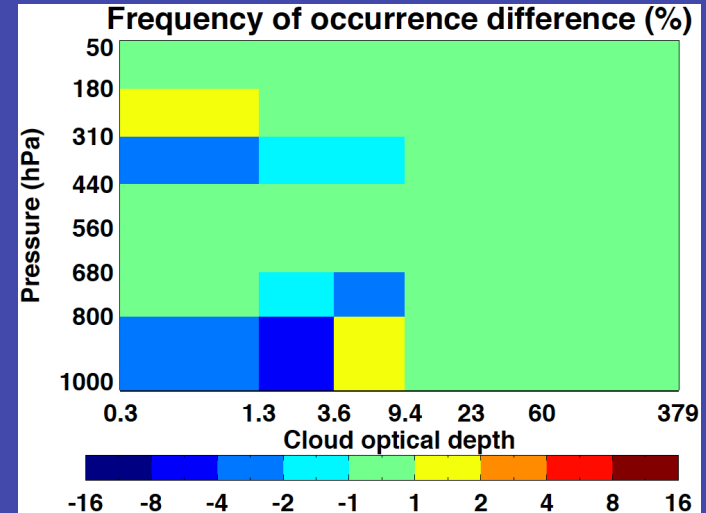
Image from Strebe, https://commons.wikimedia.org/wiki/File:Mercator_projection_SW.jpg

Cloud fraction differences (%) for HadGEM2-A-CERES: 60°N-60°S (MAM)

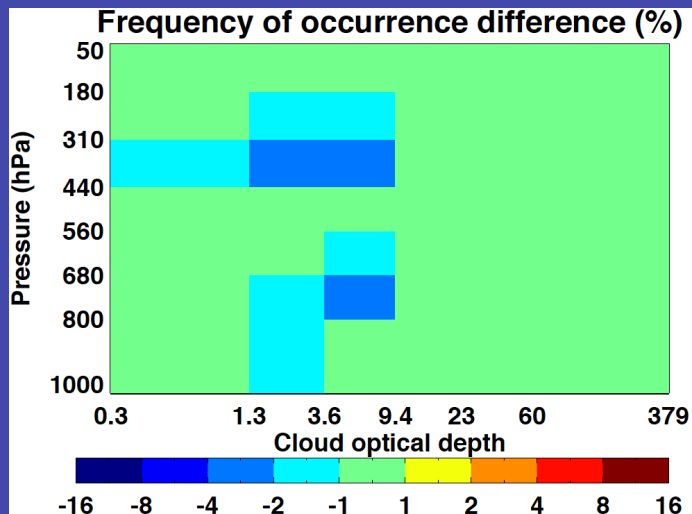
All surfaces



Ocean



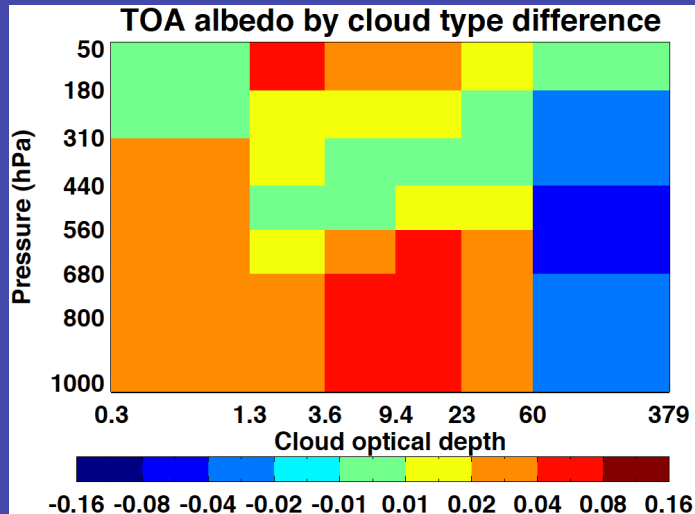
Land



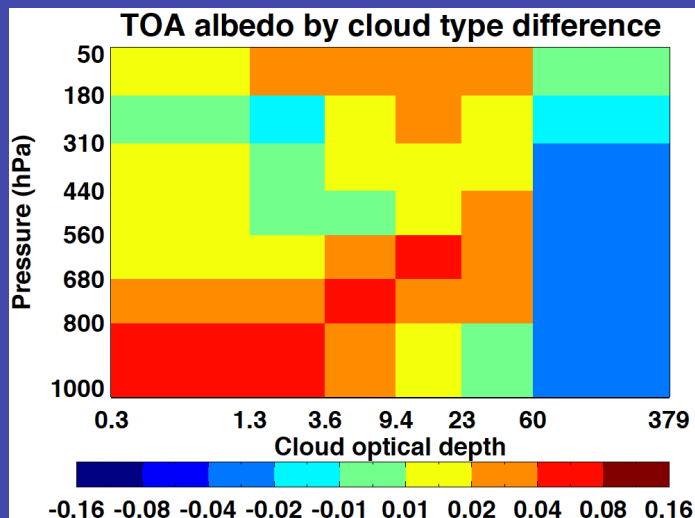
	CERES	HadGEM2-A
All sfc	0.622	0.454
Ocean	0.648	0.487
Land	0.548	0.361

TOA Shortwave albedo differences for HadGEM2-A-CERES: 60°N-60°S (MAM)

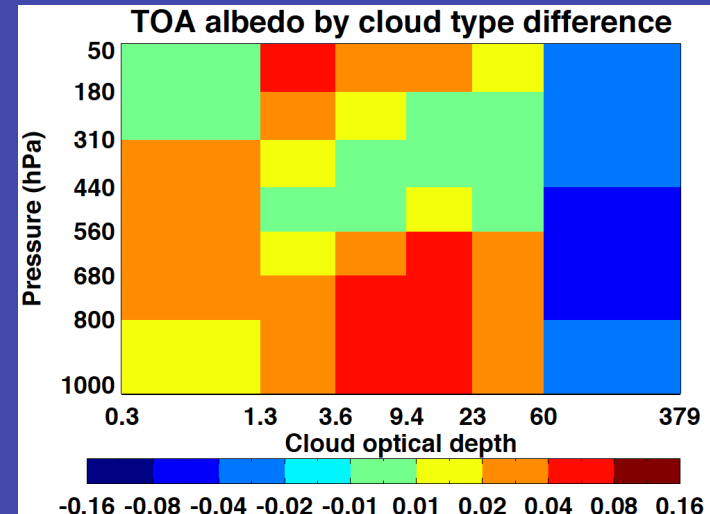
All surfaces



Land



Oceans



Southern Great Plains results

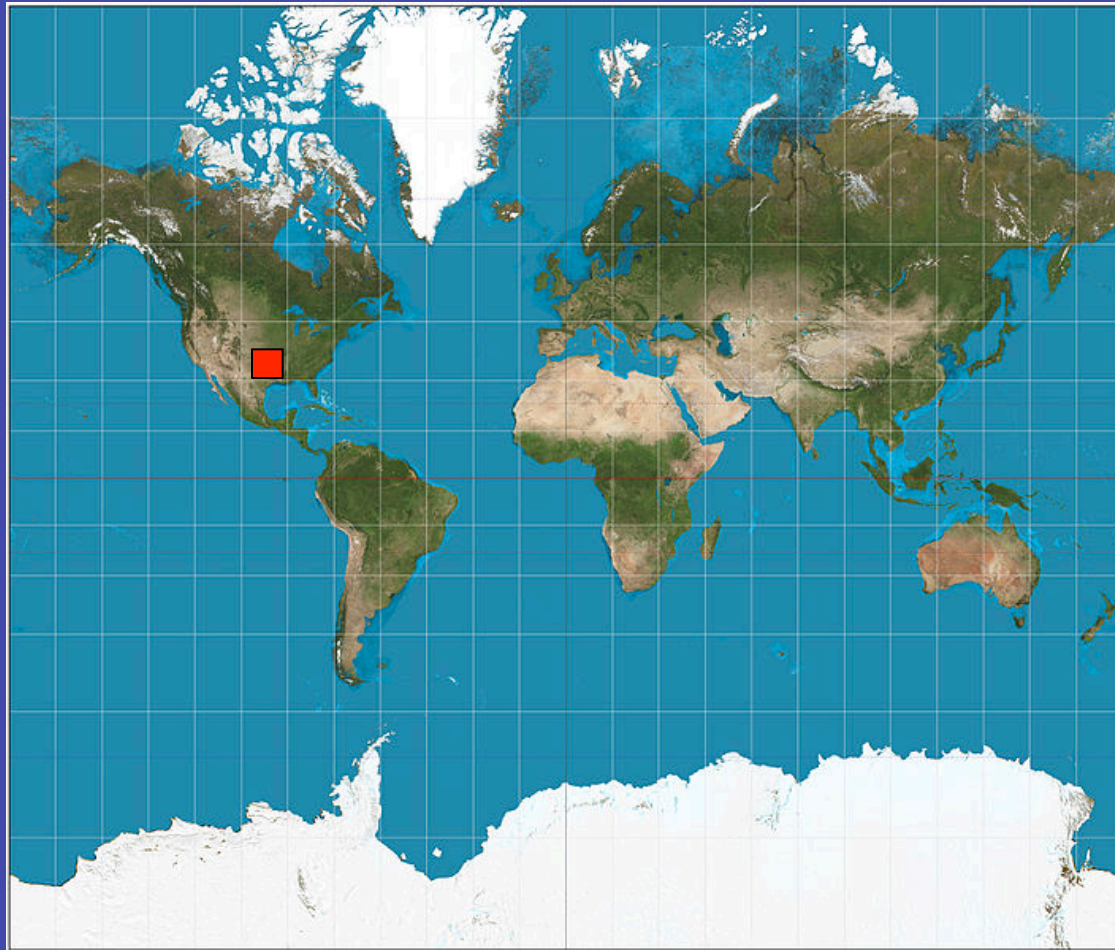
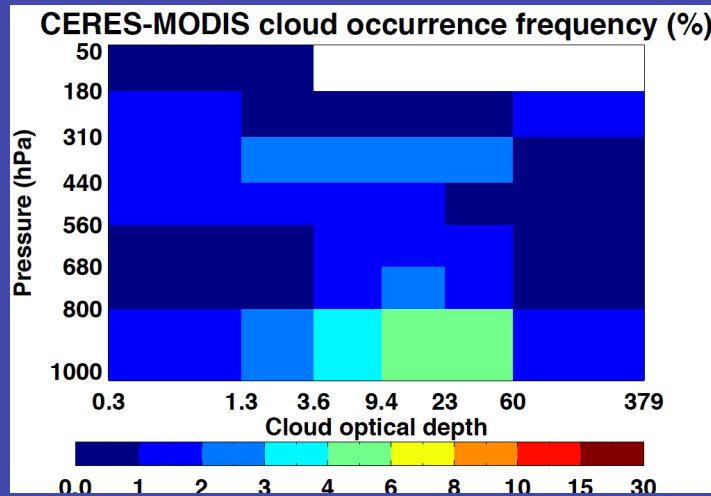


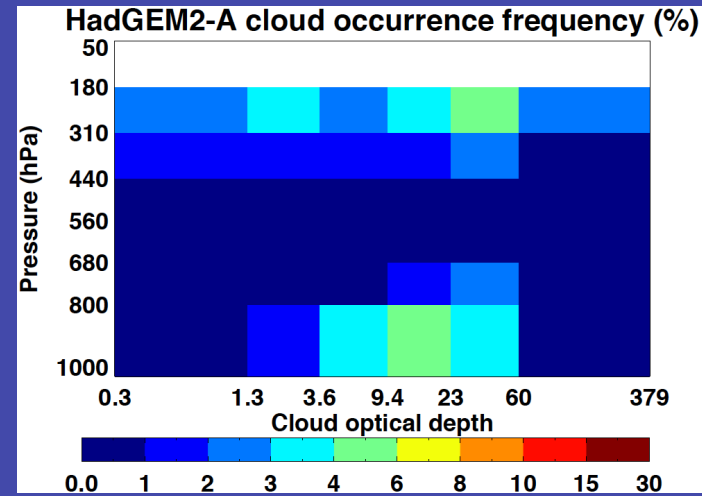
Image from Strebe, https://commons.wikimedia.org/wiki/File:Mercator_projection_SW.jpg

Cloud fraction (%) for CERES, HadGEM2-A over SGP (JFD 2008)

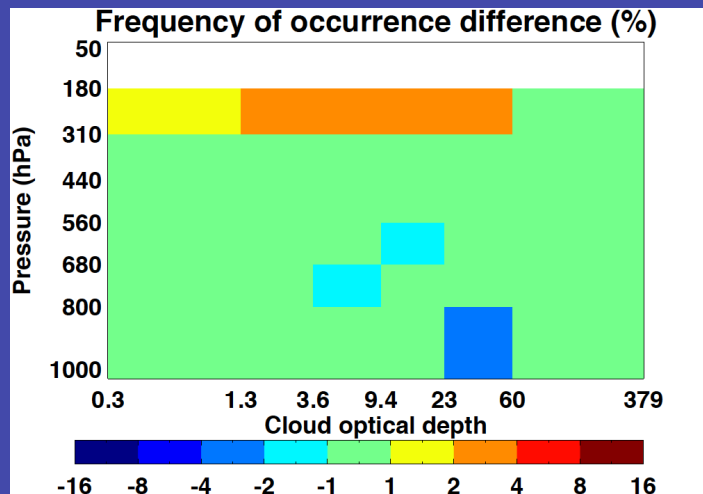
CERES



HadGEM2-A



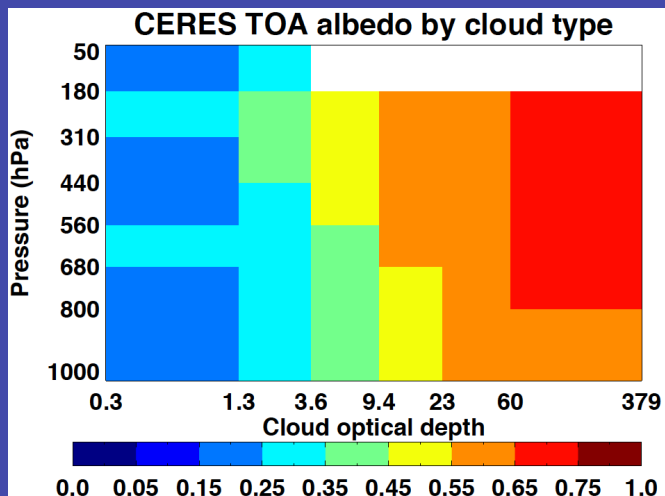
HadGEM2-A – CERES



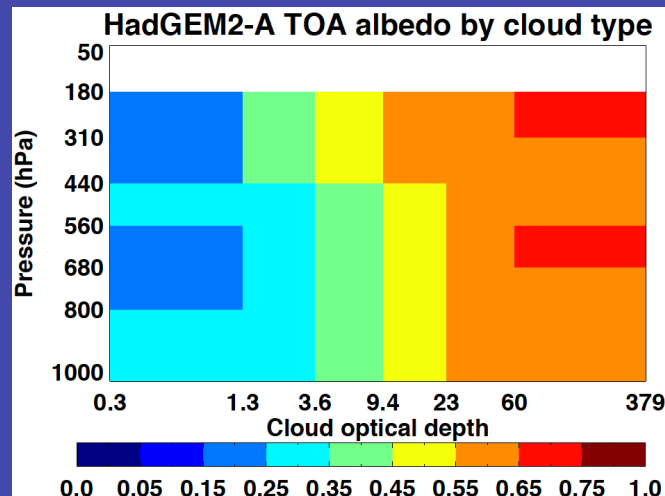
Grid-mean total cloud fraction:
CERES: 0.558
HadGEM2-A: 0.520

TOA SW albedo by cloud type for CERES, HadGEM2-A for SGP (JFD 2008)

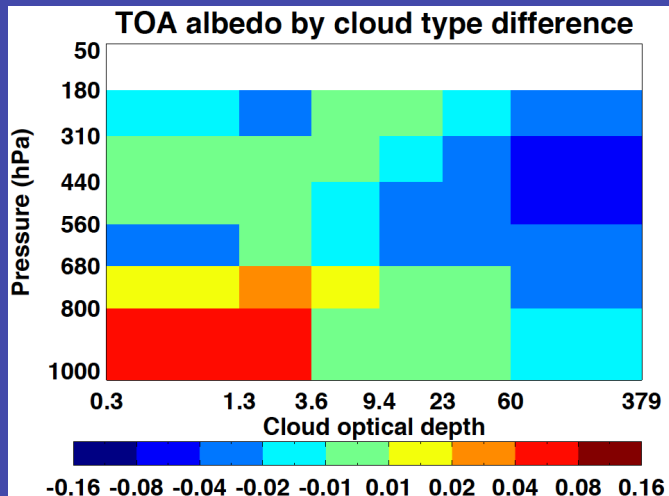
CERES



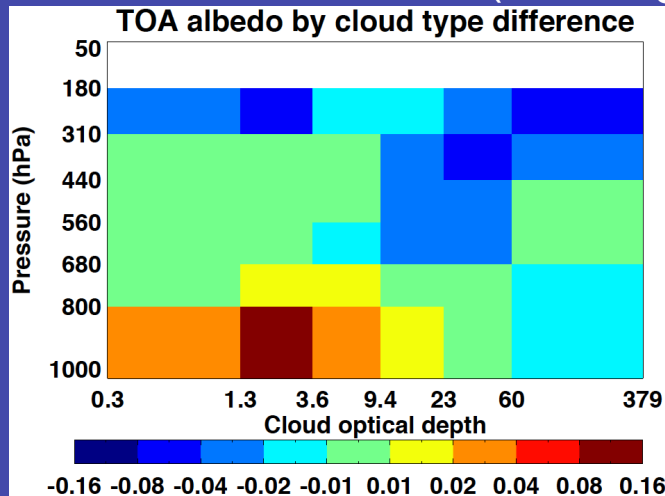
HadGEM2-A



HadGEM2-A – CERES



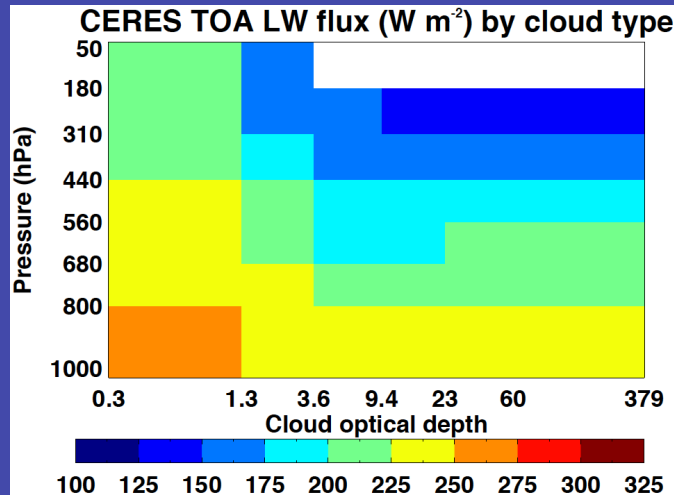
HadGEM2-A – CERES (CF-weighted)



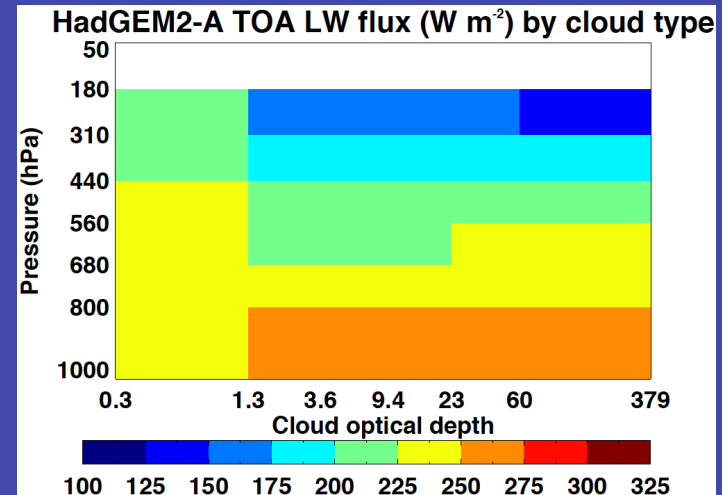
Grid-mean all-sky SW albedo: CERES: 0.350 HadGEM2-A: 0.337

TOA LW flux by cloud type (W m^{-2}) for CERES, HadGEM2-A over SGP (JFD 2008)

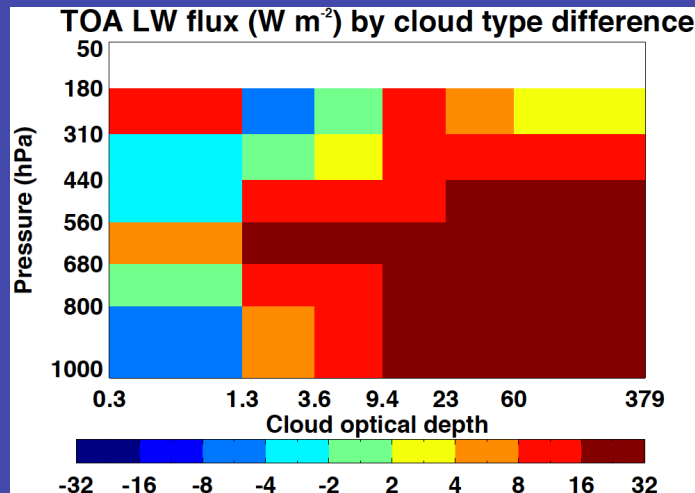
CERES



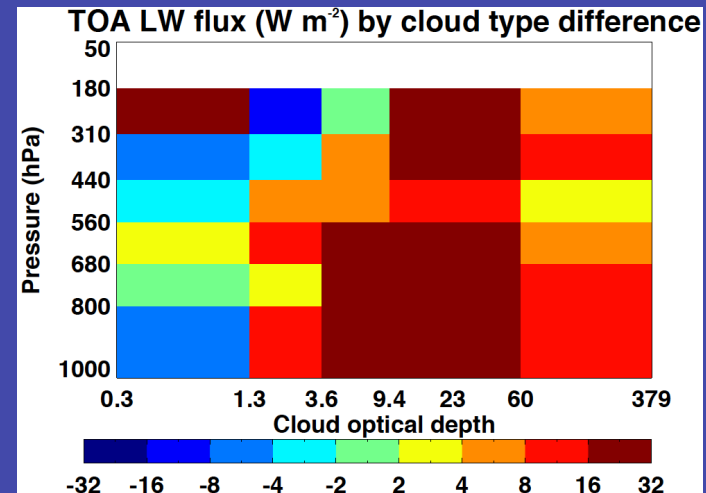
HadGEM2-A



HadGEM2-A – CERES



HadGEM2-A – CERES (CF-weighted)



Grid-mean all-sky OLR: CERES: 233.4 W m^{-2} HadGEM2-A: 236.7 W m^{-2}

Summary

- Identifying unique subcolumns reduces the number of RT calculations required by >95%.
- Both LW and SW biases (RT model - HadGEM2-A) are relatively small and negative, while RMS errors seem reasonable.
- Over the SE Pacific, HadGEM2-A produces low clouds, but they tend to be too few and too thick, and are too bright by cloud type, when comparing to CERES FluxByCloudTyp product. This is an enhanced version of the “too few, too bright” error noted by Nam et al. (2012).
- There are similar errors for the 60° N – 60° S domain, especially over the oceans.
- Over the Southern Great Plains, the cloud fraction is realistic, with too many high clouds, but OLR is too high for most cloud types, these offsetting errors produce an OLR that is close to observed.

Extra Slides

Summary

- Identifying unique subcolumns reduces the number of RT calculations required by >95%.
- Both LW and SW biases (RT model - HadGEM2-A) are relatively small and negative, while RMS errors seem reasonable.
- Over the SE Pacific, HadGEM2-A produces low clouds, but they tend to be too few and too thick, and are too bright by cloud type, when comparing to CERES FluxByCloudTyp product.
- Over the Equatorial Pacific, HadGEM2-A produces too few clouds, resulting in an unrealistically high all-sky OLR, even though the OLR by cloud type has both positive and negative differences from observations.
- Over the Southern Great Plains, the cloud fraction is realistic, with too many high clouds, but OLR is too high for most cloud types, these offsetting errors produce an OLR that is close to observed.

DPI Results: SE Pacific JJA 2008

- Observed cloud fraction: 0.801 daily
- Simulated cloud fraction: 0.658
- Observed OLR: 279.9
- Simulated OLR: 286.8 (289.0 norm)
- Observed clear-sky OLR: 287.1
- Simulated clear-sky OLR: 296.7 (298.7 norm)
- Observed TOA albedo: 0.274
- Simulated TOA albedo: 0.315 (0.324 norm)
- Observed clear-sky TOA albedo: 0.093
- Simulated clear-sky TOA albedo: 0.092 (0.095 norm)

DPI Results: EQ Pacific JJA 2008

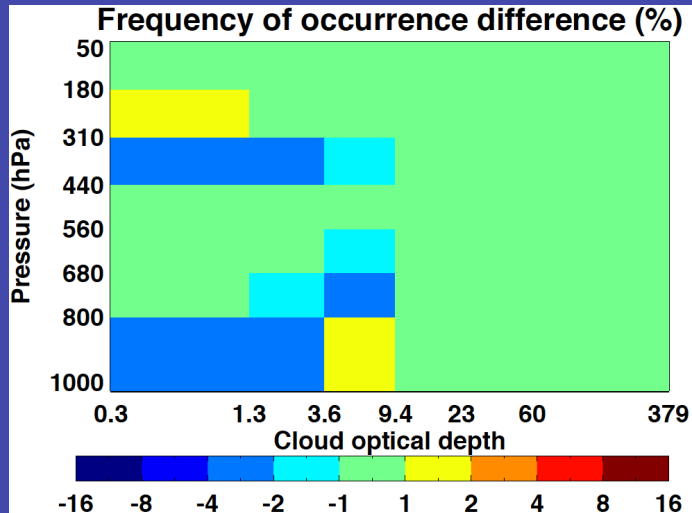
- Observed cloud fraction: 0.609 daily
- Simulated cloud fraction: 0.366
- Observed OLR: 236.6
- Simulated OLR: 257.4 (258.7 norm)
- Observed clear-sky OLR: 279.8
- Simulated clear-sky OLR: 284.9 (286.1 norm)
- Observed TOA albedo: 0.196
- Simulated TOA albedo: 0.174 (0.176 norm)
- Observed clear-sky TOA albedo: 0.072
- Simulated clear-sky TOA albedo: 0.077 (0.078 norm)

DPI Results: SGP Jan-Feb-Dec 2008

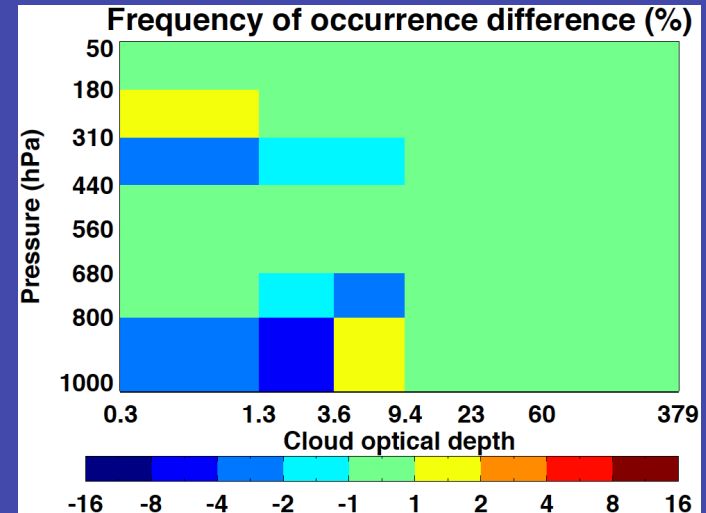
- Observed cloud fraction: 0.558 daily
- Simulated cloud fraction: 0.520
- Observed OLR: 233.4
- Simulated OLR: 236.6 (236.7 norm)
- Observed clear-sky OLR: 262.7
- Simulated clear-sky OLR: 270.1 (269.3 norm)
- Observed TOA albedo: 0.350
- Simulated TOA albedo: 0.343 (0.337 norm)
- Observed clear-sky TOA albedo: 0.192
- Simulated clear-sky TOA albedo: 0.171 (0.168 norm)

Cloud fraction differences (%) for HadGEM2-A-CERES: 60°N-60°S (MAM)

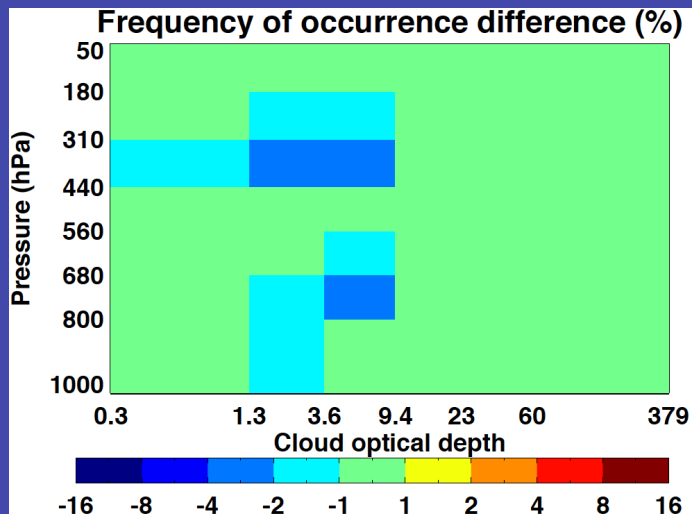
All surfaces



Ocean

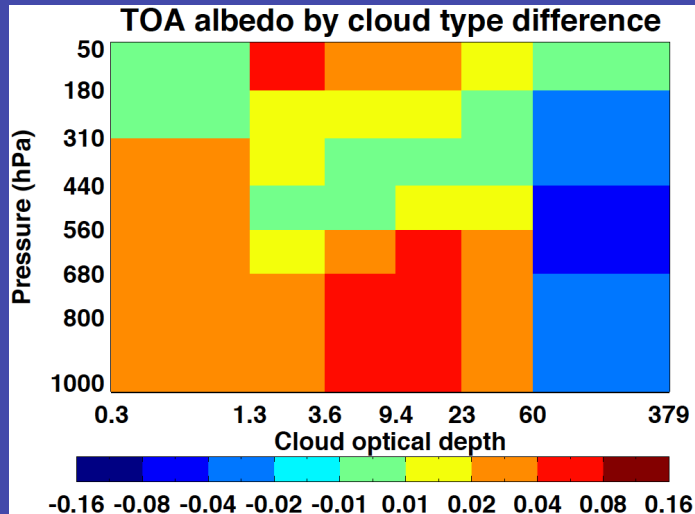


Land

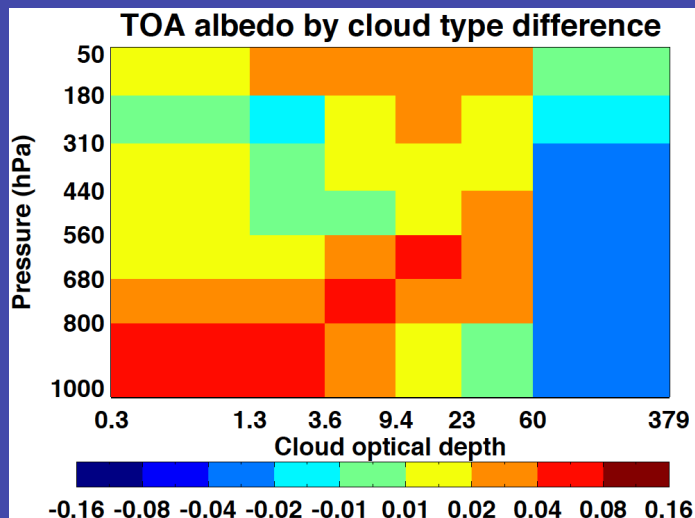


TOA Shortwave albedo differences for HadGEM2-A-CERES: 60°N-60°S (MAM)

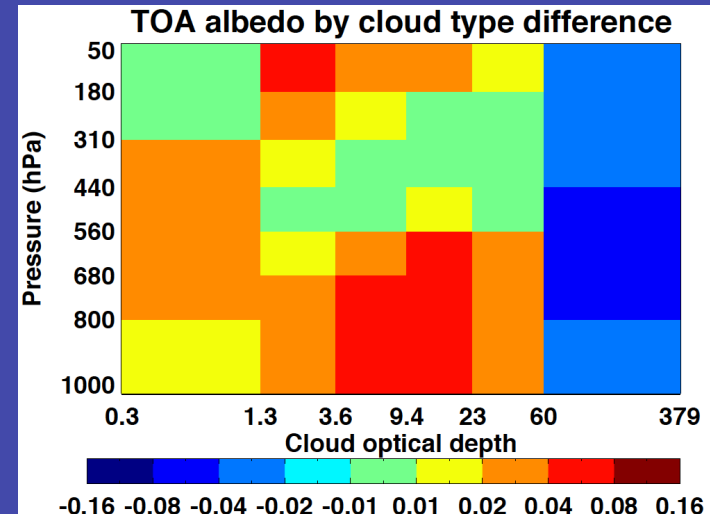
All surfaces



Land

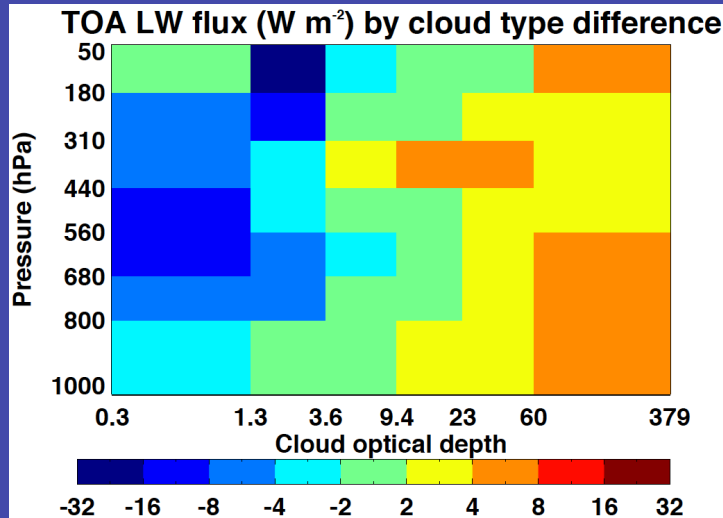


Oceans

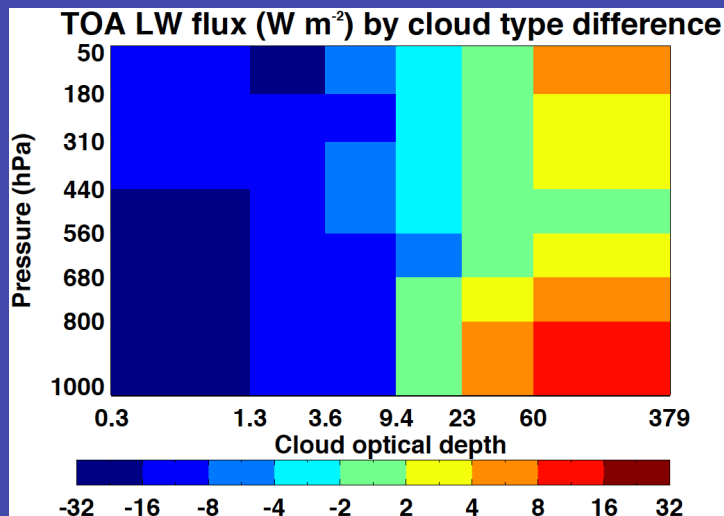


TOA OLR differences for HadGEM2-A-CERES: 60°N-60°S (MAM)

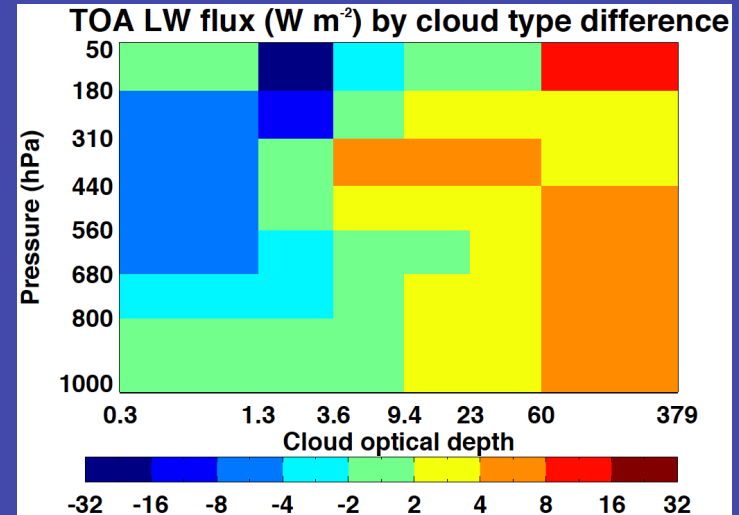
All surfaces



Land



Oceans



Equatorial Pacific results

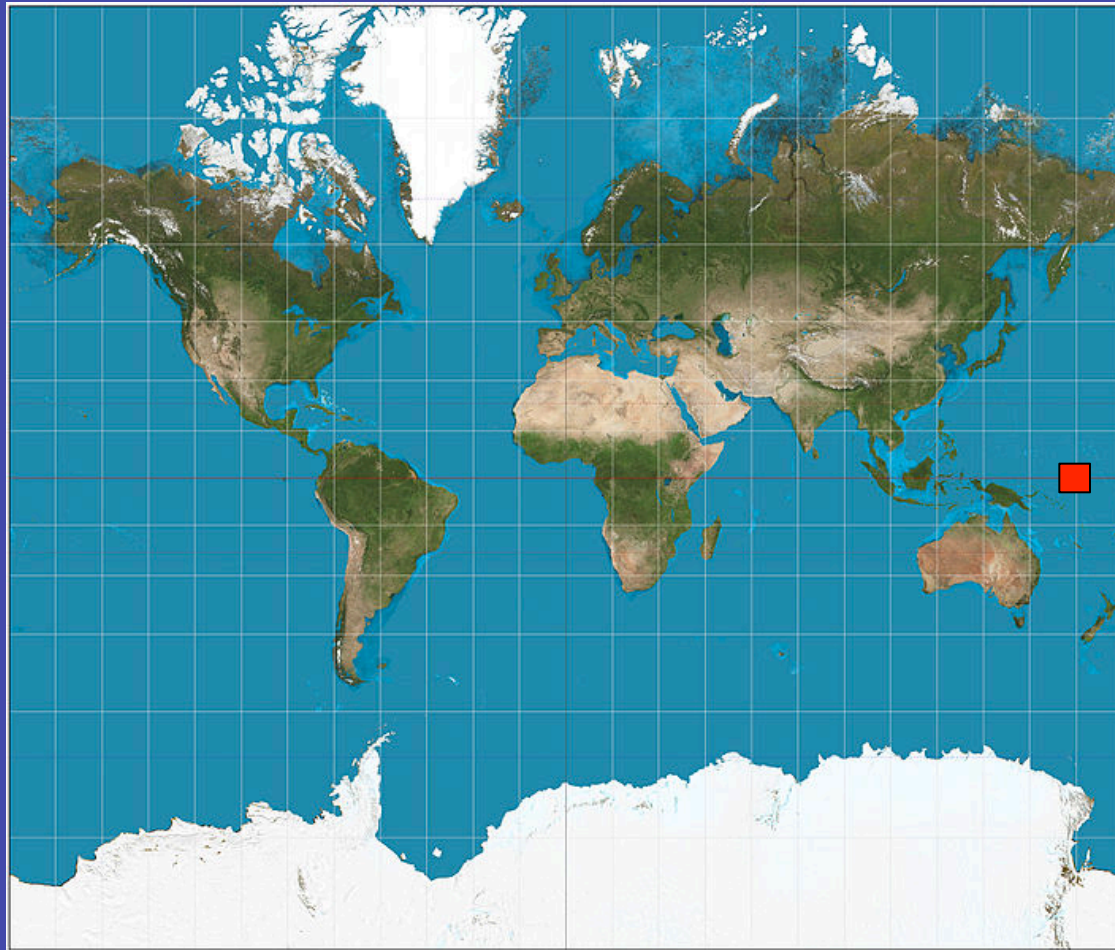
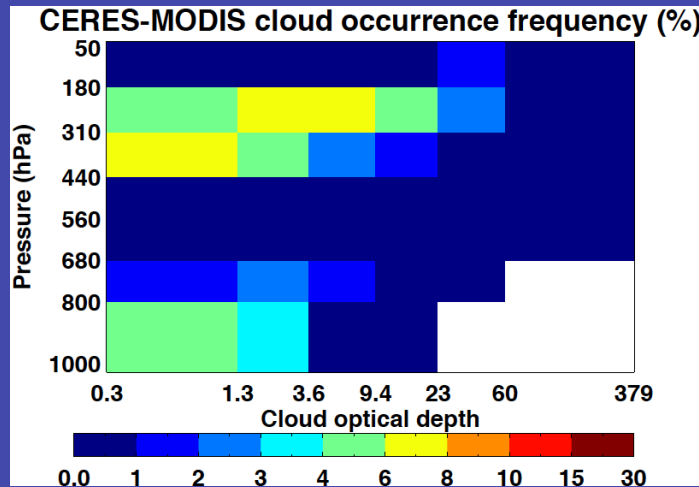


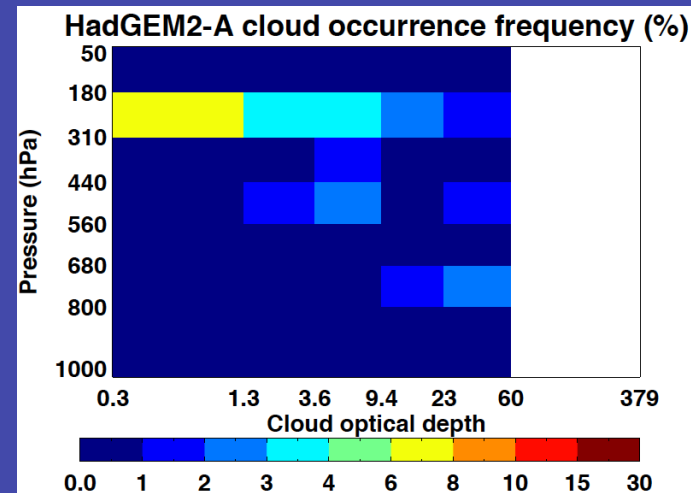
Image from Strebe, https://commons.wikimedia.org/wiki/File:Mercator_projection_SW.jpg

Cloud fraction (%) for CERES, HadGEM2-A over Equatorial Pacific (JJA 2008)

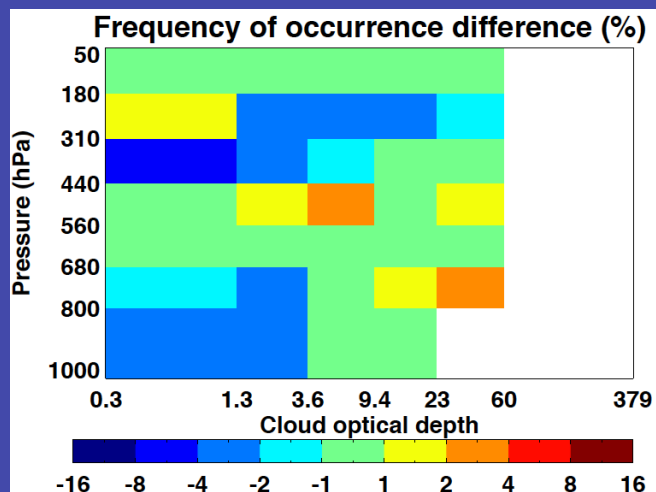
CERES



HadGEM2-A



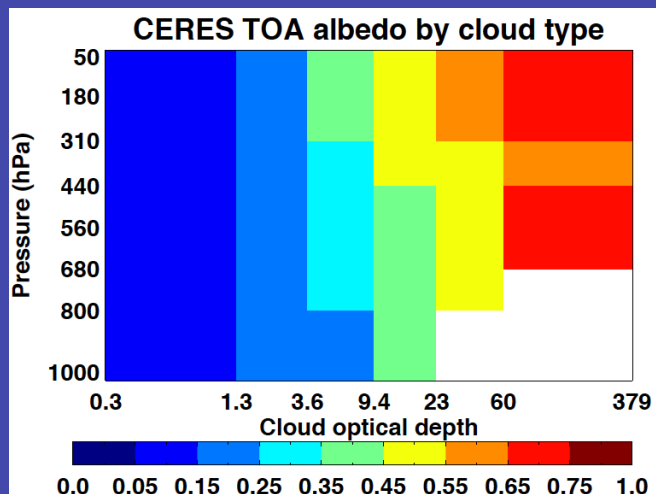
HadGEM2-A – CERES



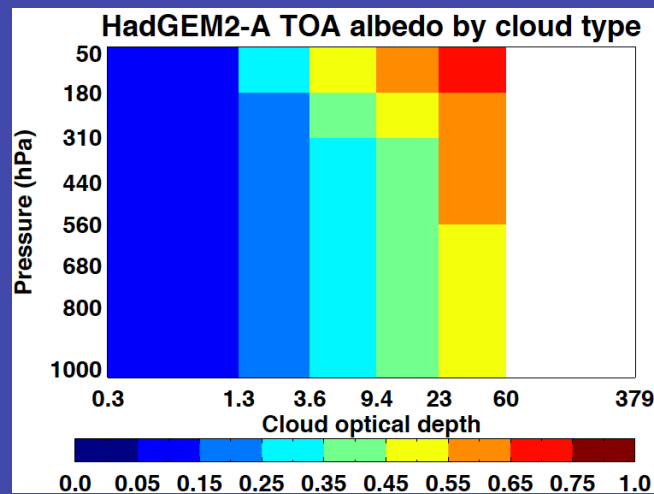
Grid-mean total cloud fraction:
CERES: 0.609
HadGEM2-A: 0.366

TOA SW albedo by cloud type for CERES, HadGEM2-A for Equatorial Pacific (JJA 2008)

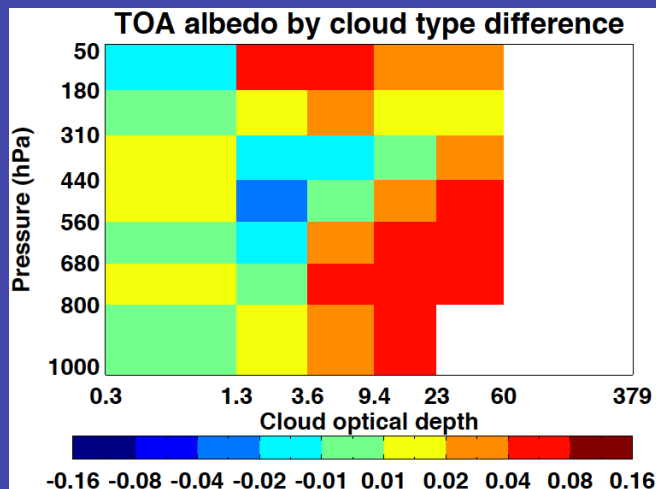
CERES



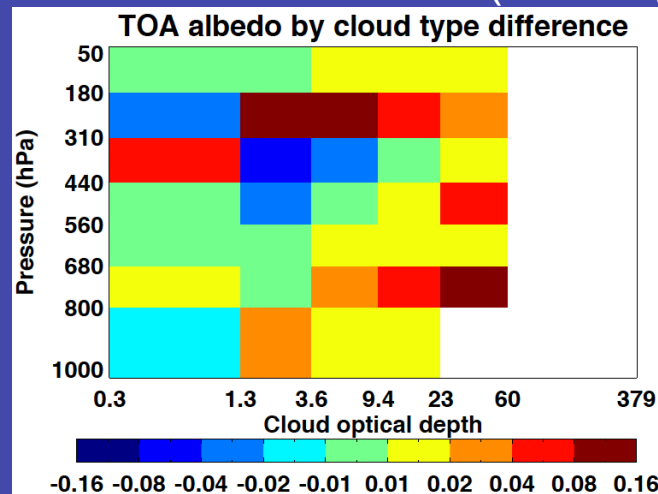
HadGEM2-A



HadGEM2-A – CERES



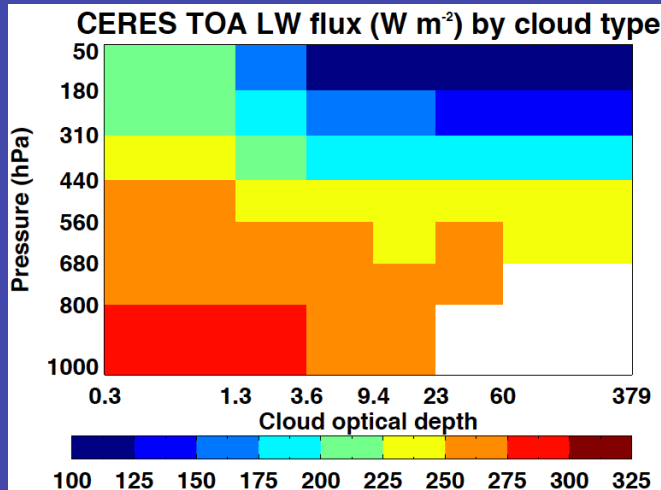
HadGEM2-A – CERES (CF-weighted)



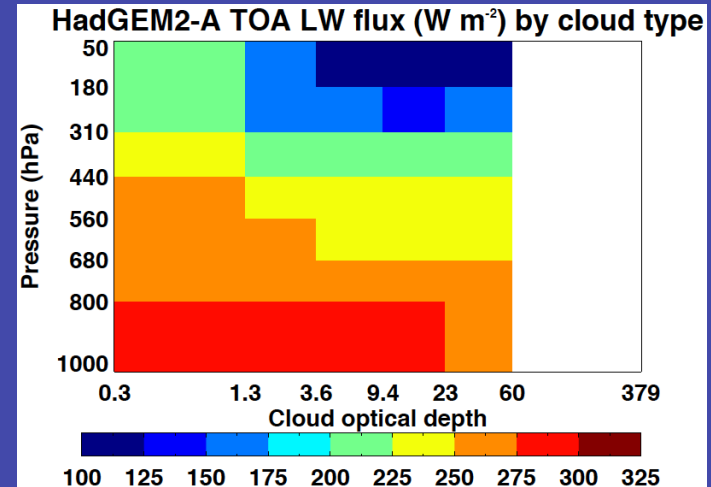
Grid-mean all-sky SW albedo: CERES: 0.196 HadGEM2-A: 0.176

TOA LW flux by cloud type (W m^{-2}) for CERES, HadGEM2-A over Equatorial Pacific (JJA 2008)

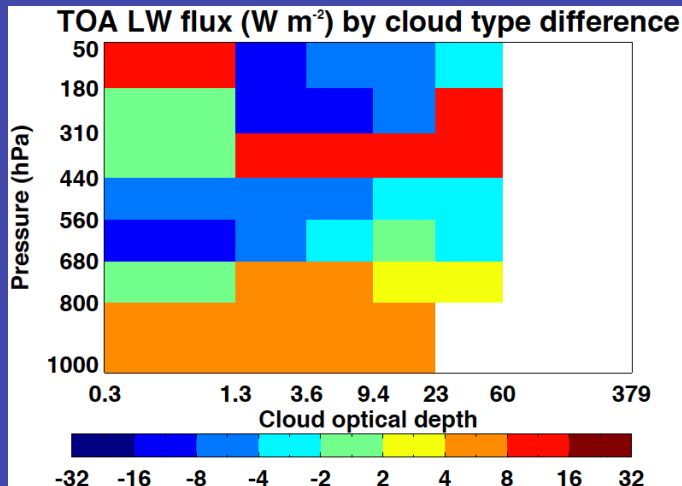
CERES



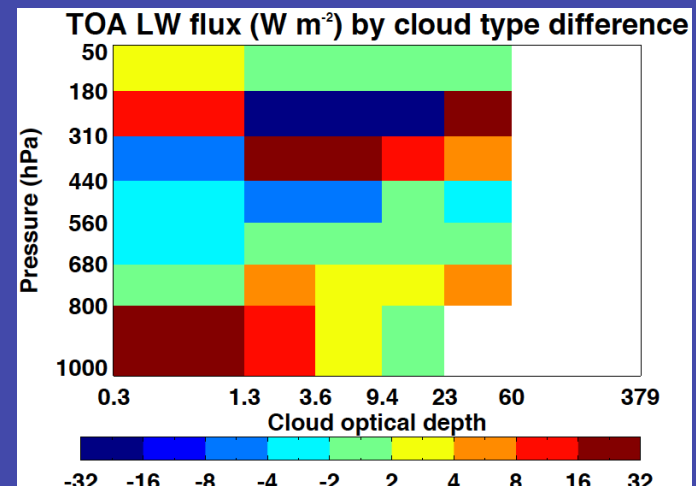
HadGEM2-A



HadGEM2-A – CERES



HadGEM2-A – CERES (CF-weighted)



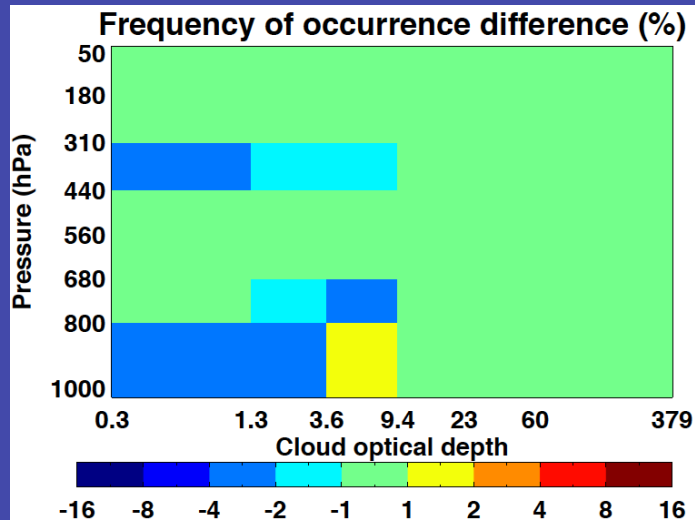
Grid-mean all-sky OLR: CERES: 236.6 W m^{-2} HadGEM2-A: 258.7 W m^{-2}

60° N- 60° S Cloud fraction

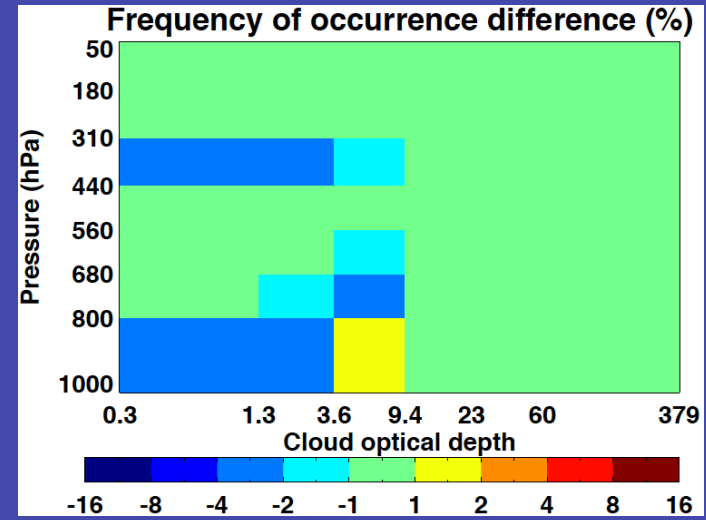
	All sfc (sim)	Ocean (sim)	Land (sim)	All sfc (obs)	Ocean (obs)	Land (obs)
JFD 2008	0.465	0.491	0.393	0.632	0.662	0.546
MAM 2008	0.454	0.487	0.361	0.622	0.648	0.548
JJA 2008	0.461	0.519	0.300	0.623	0.661	0.516
SON 2008	0.453	0.500	0.320	0.630	0.666	0.528

Cloud fraction differences (%) for HadGEM2-A-CERES: 60°N-60°S (all)

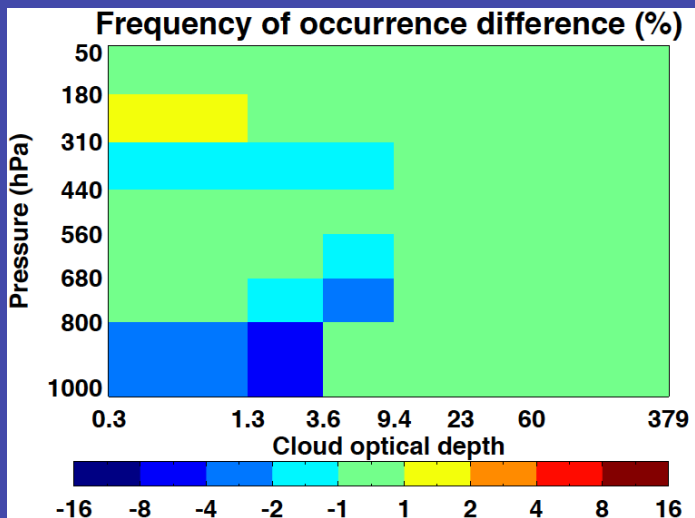
JFD



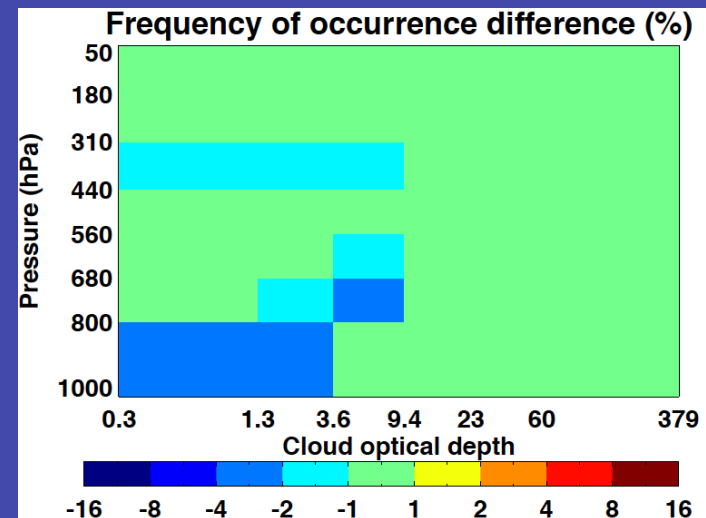
MAM



JJA

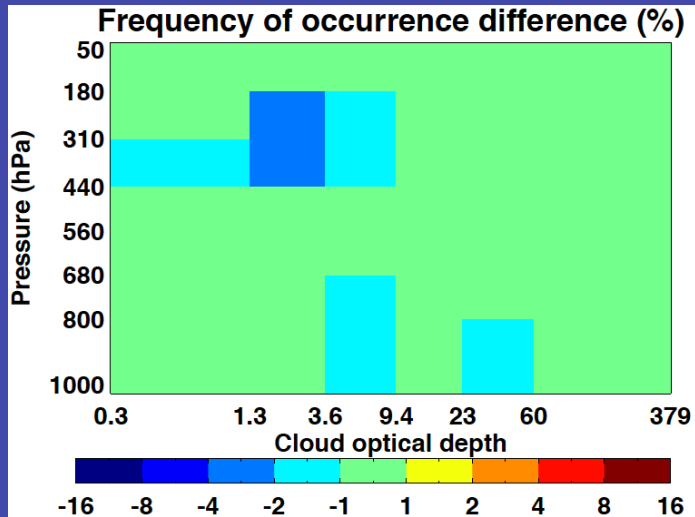


SON

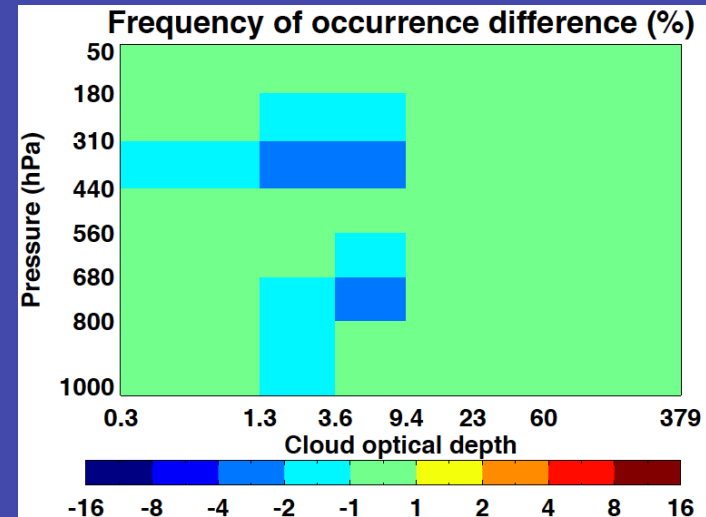


Cloud fraction differences (%) for HadGEM2-A-CERES: 60°N-60°S (land)

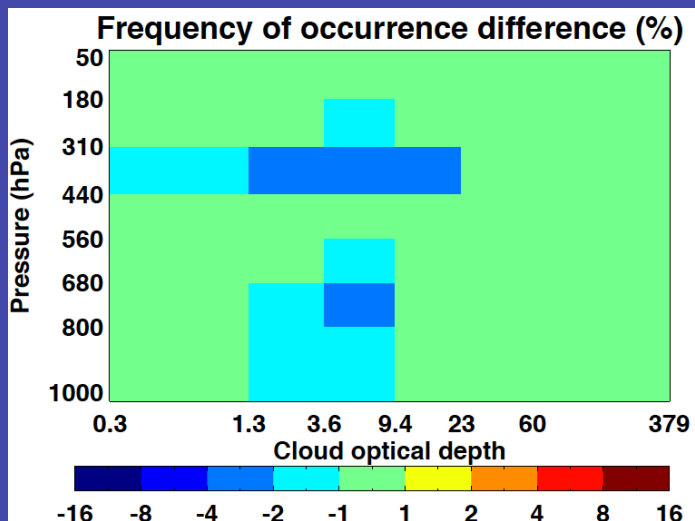
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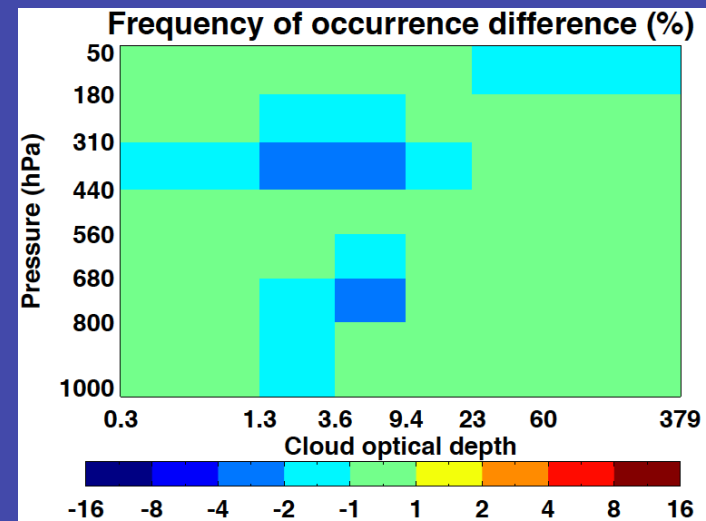
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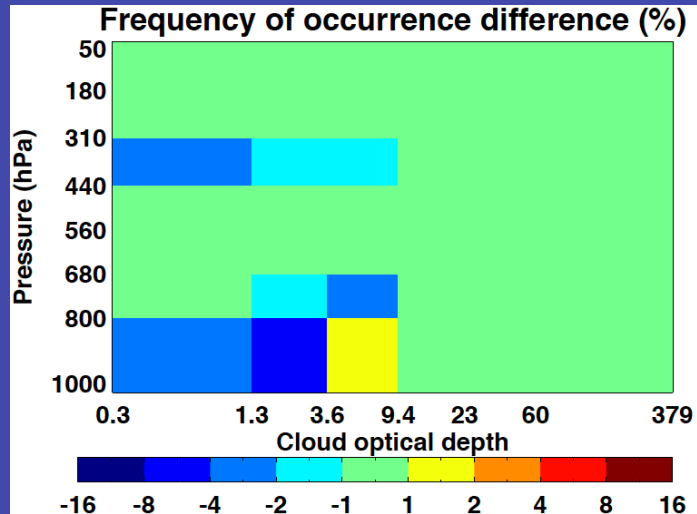


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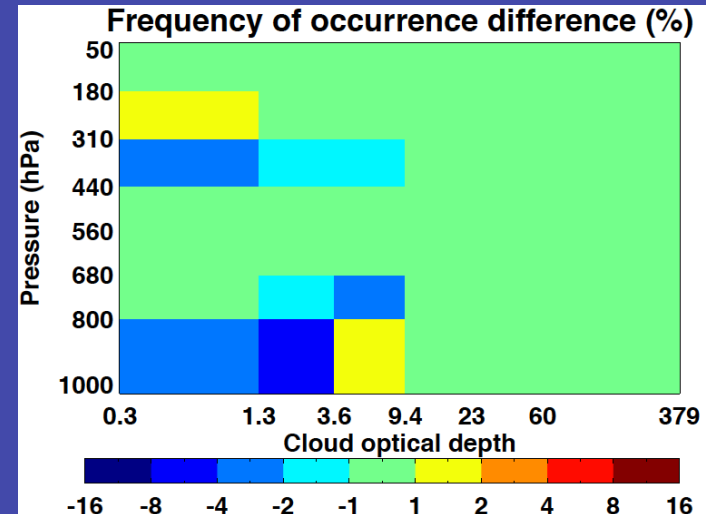


Cloud fraction differences (%) for HadGEM2-A-CERES: 60°N-60°S (ocean)

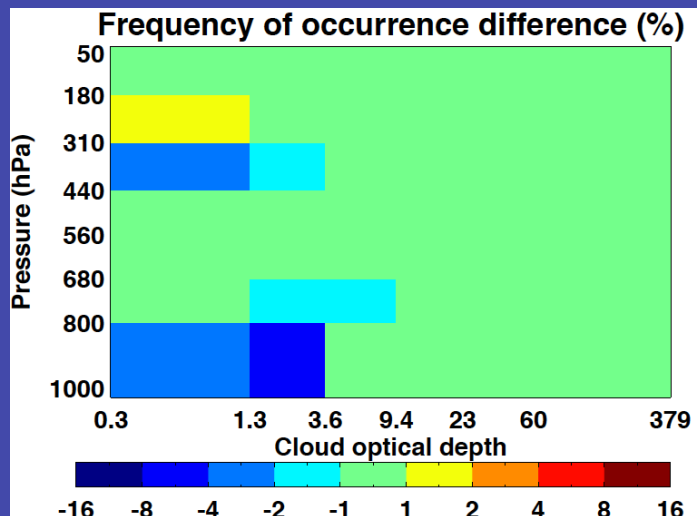
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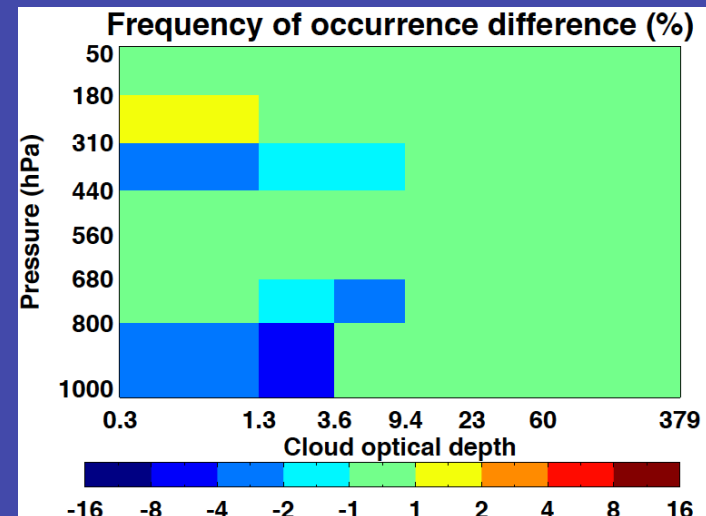
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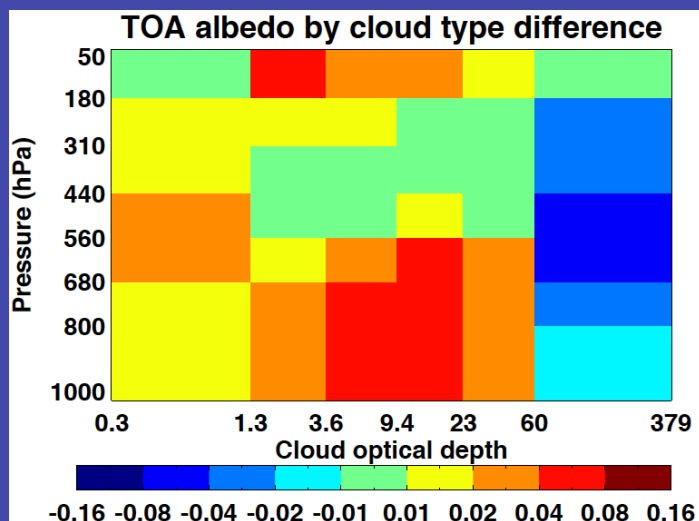


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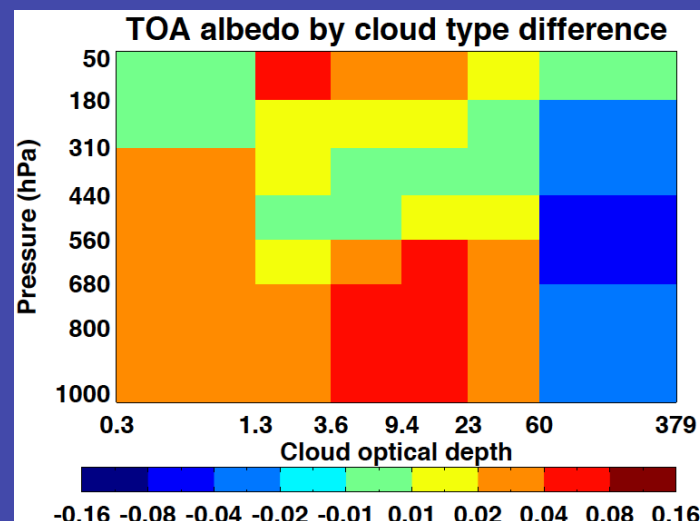


TOA Shortwave albedo differences for HadGEM2-A-CERES: 60°N-60°S (all)

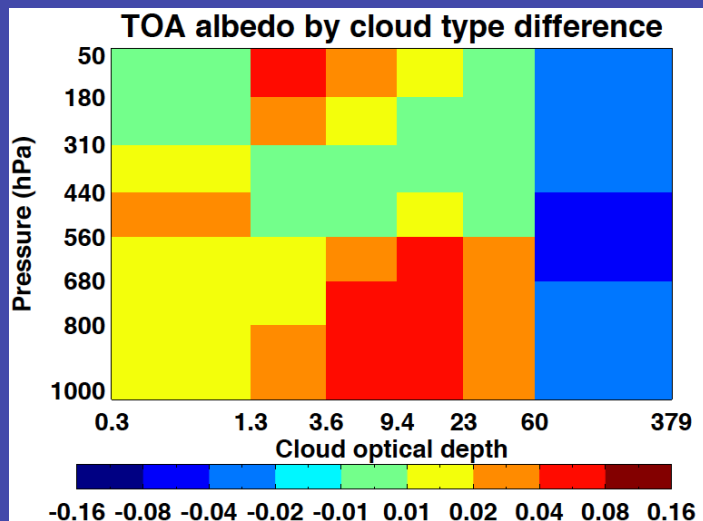
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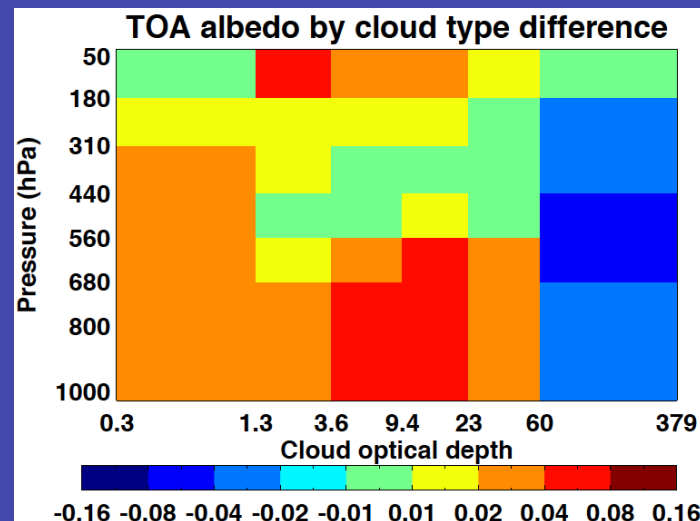
MAM



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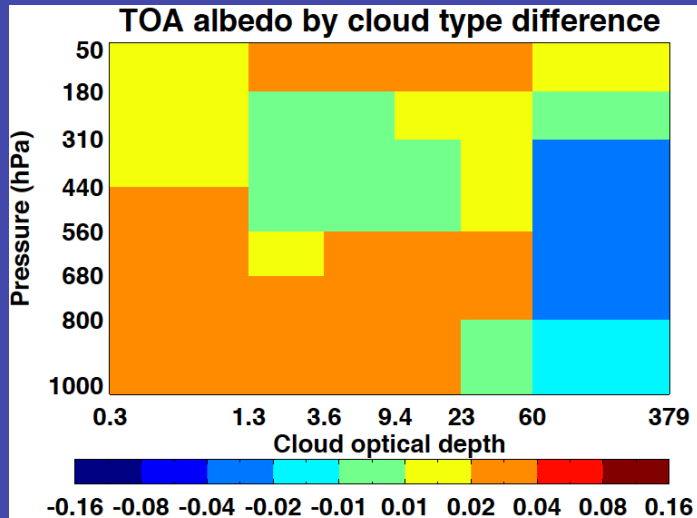


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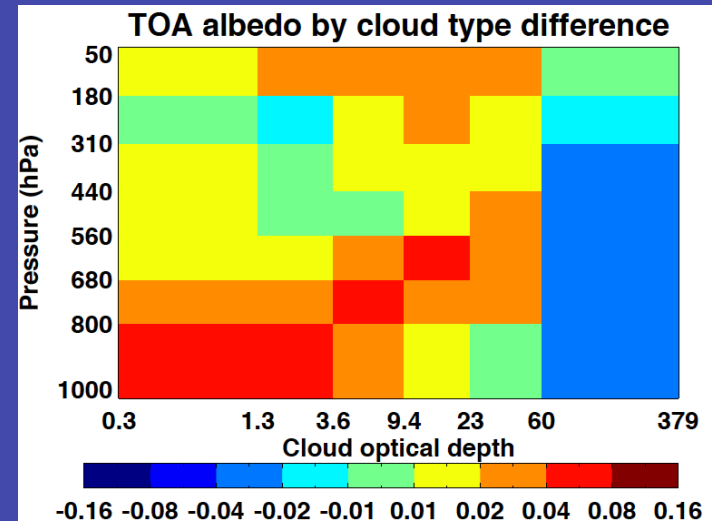


TOA Shortwave albedo differences for HadGEM2-A-CERES: 60°N-60°S (land)

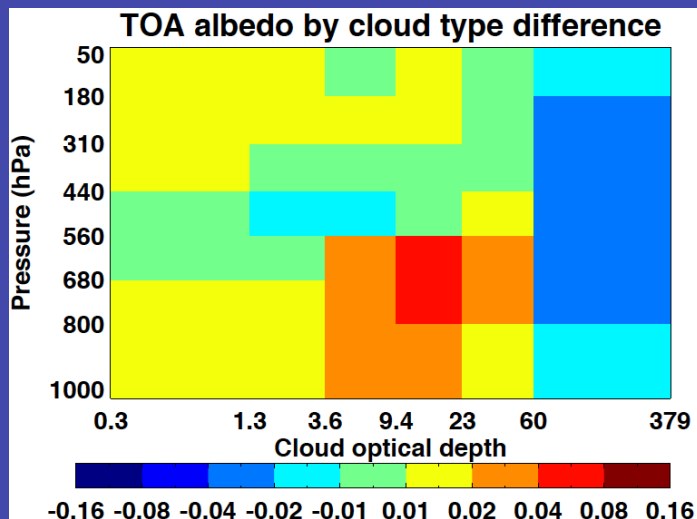
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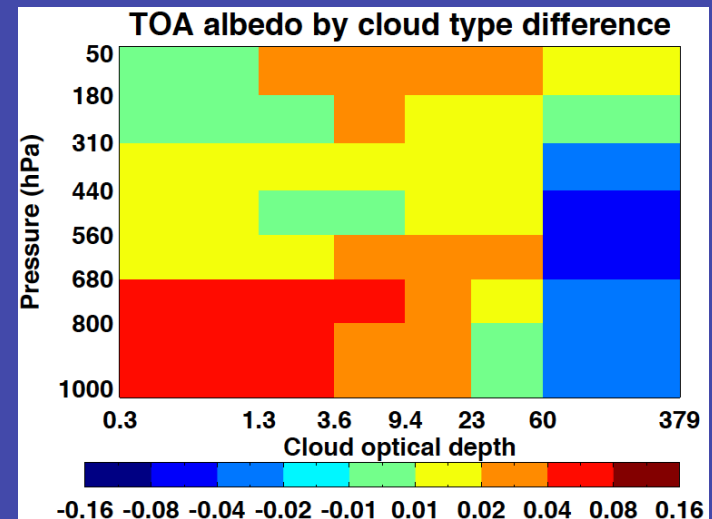
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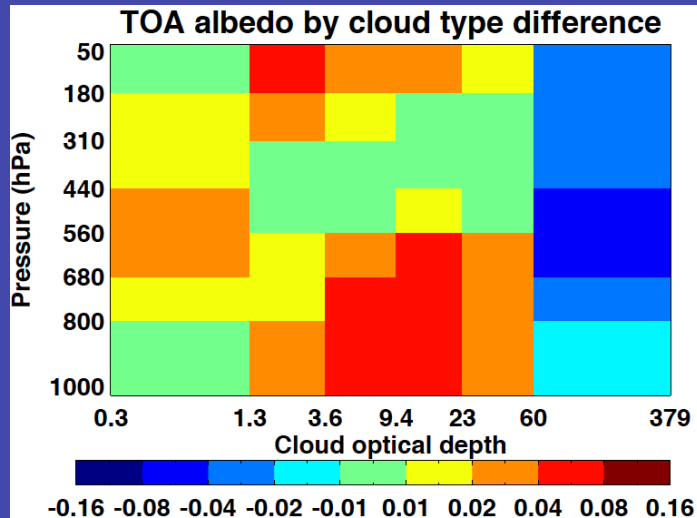


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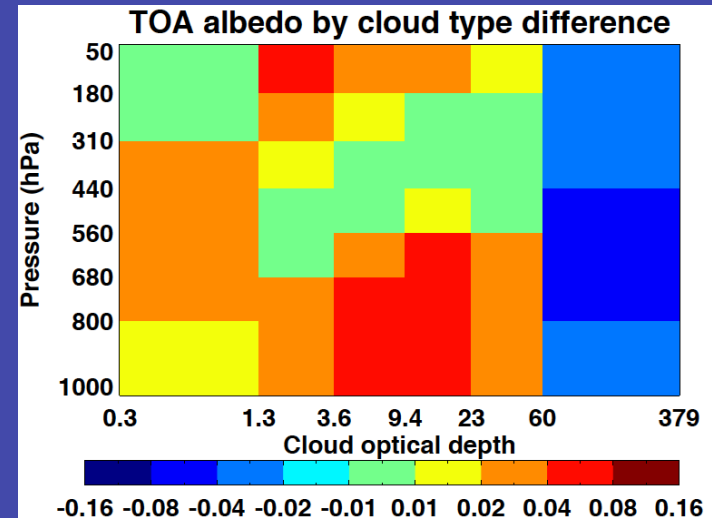


TOA Shortwave albedo differences for HadGEM2-A-CERES: 60°N-60°S (ocean)

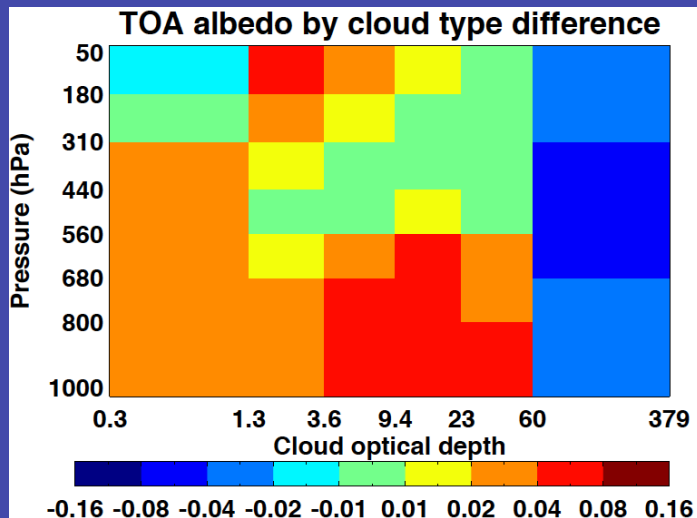
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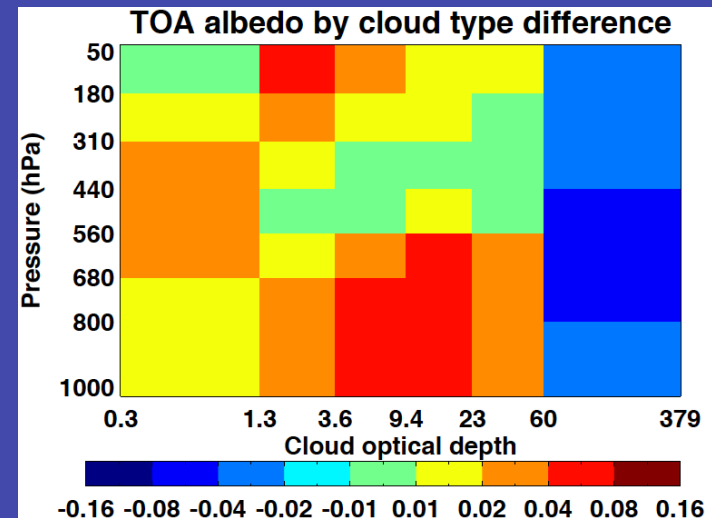
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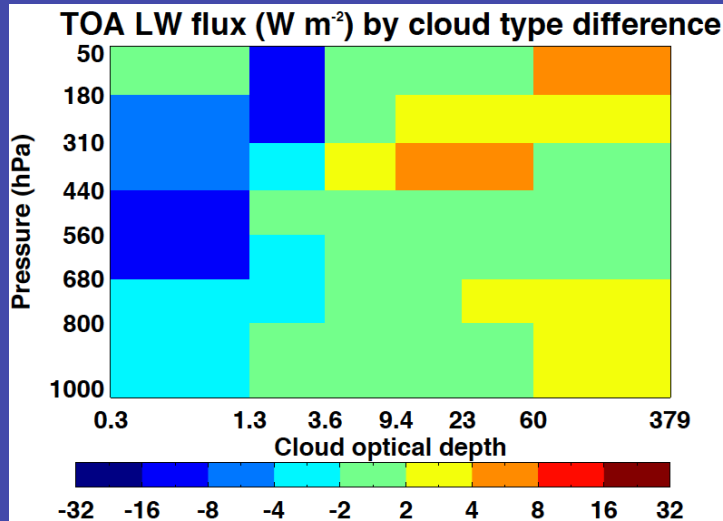


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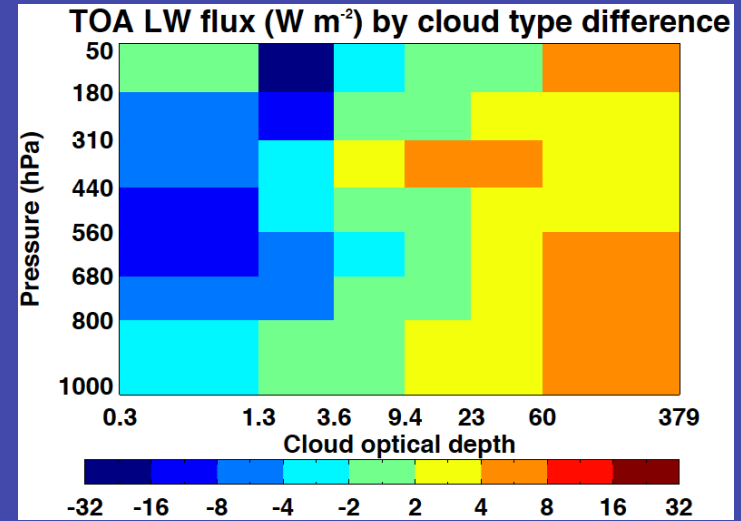


TOA OLR differences for HadGEM2-A-CERES: 60°N-60°S (all)

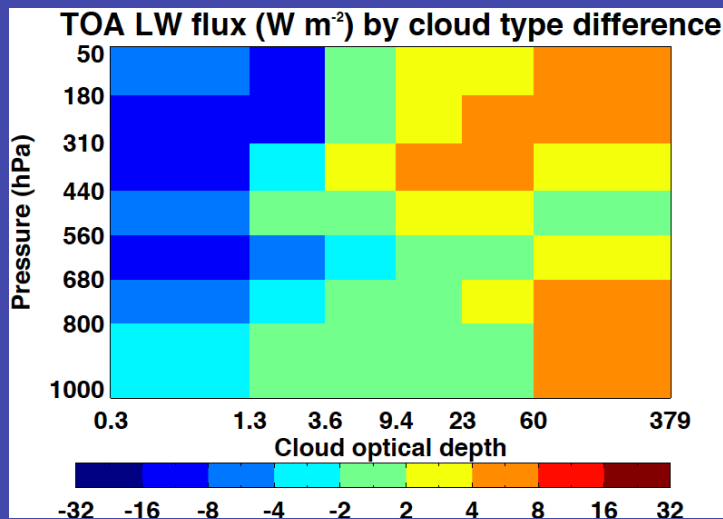
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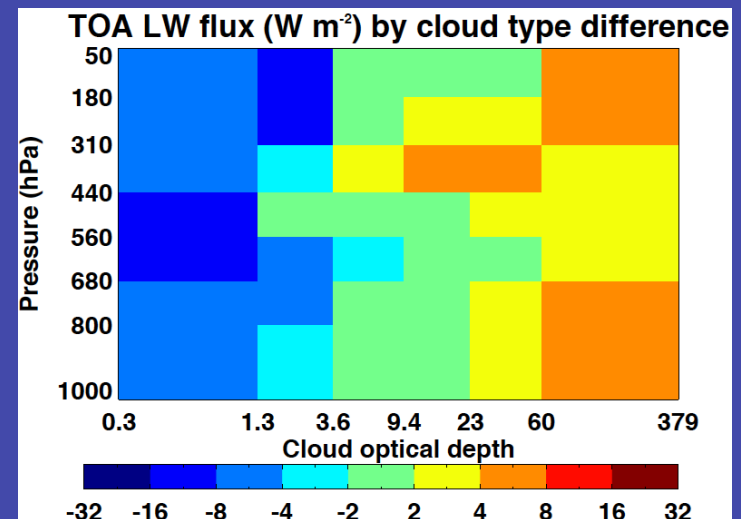
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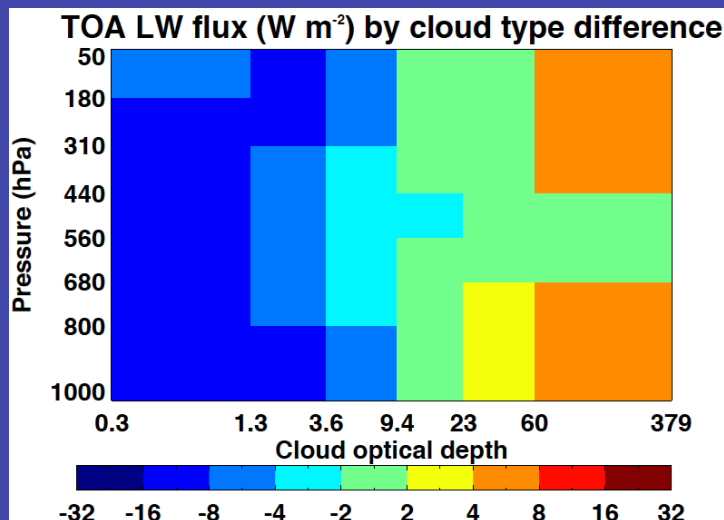


SON

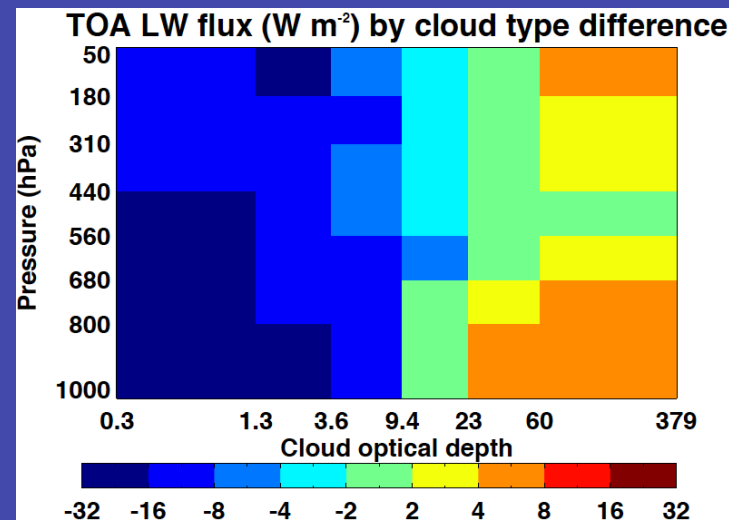


TOA OLR differences for HadGEM2-A-CERES: 60°N-60°S (land)

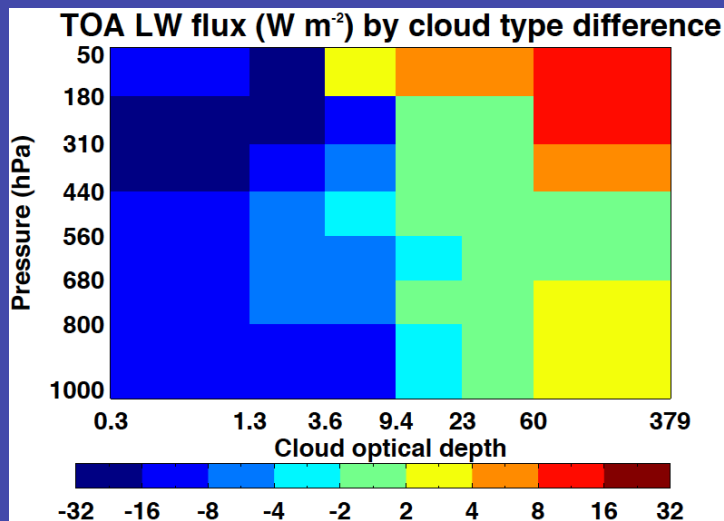
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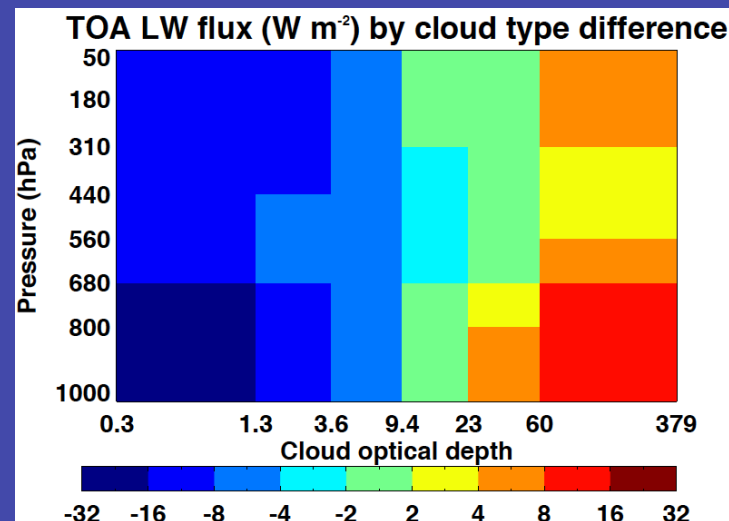
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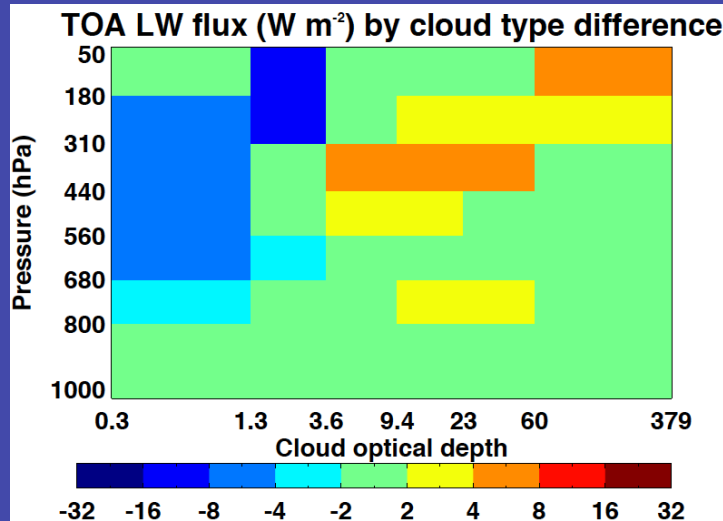


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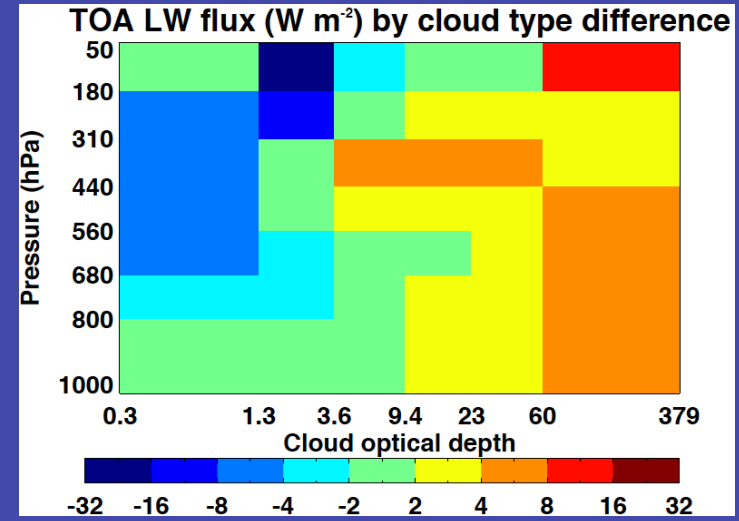


TOA OLR differences for HadGEM2-A-CERES: 60°N-60°S (ocean)

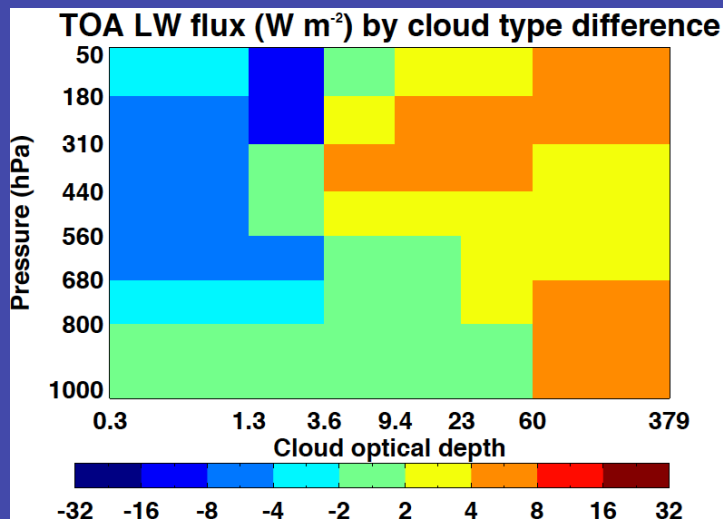
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